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THE RELATIONSHIP BETWEEN SELECTED ROENTGENOGRAM MEASUREMENTS OF THE KNEE AND CHONDROMALACIA PATELLA

by

© ROBERTA NOWLAN-SMITH

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

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.....
Supervisor

.....

.....

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Date June 15, 1981

DEDICATION

To my parents who taught me never to quit.

ABSTRACT

The purpose of this study was to assess the relationship of selected radiographic measurements, namely sulcus angle, congruence angle, lateral patello-femoral angle, lateral patellar displacement, patella height and patella configuration, to chondromalacia of the patella. The study was designed as a retrospective analysis of patients diagnosed as having chondromalacia of the patella, between the years 1974 and 1981. The subjects consisted of sixty females ranging in age from fifteen to thirty-five years, who had been examined by a group of orthopaedic surgeons at The University of Alberta Hospital, Edmonton, Alberta.

The data was analyzed using a Chi-square test for nominal data, and a t-test and difference in proportion test for correlated samples. In accordance with the limitations and delimitations imposed on the study, there were a significantly greater frequency of abnormal measurements in the chondromalacia patella group as compared to the normal populations reported in the literature, at the .01 or .001 level of confidence.

The data did not show the measurement values in the twenty degree tangential radiographic view to be significantly different from those found in the forty-five degree view except for measurements on the sulcus angle. The latter showed a significant difference at the .02 and .01 level on the left and right knee, respectively, between the two views.

It was concluded that anatomical and functional malalignments are present in many cases of chondromalacia of the patella which can readily be assessed on a twenty degree or a forty-five degree tangential x-ray

view of the patello-femoral joint and on a ninety degree lateral x-ray view of the knee joint. Measurements can then be made on these radiographs which will allow a more definite means of diagnosing the disorder and a more objective means of determining the type of treatment to institute for each patient.

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Chapter 1

THE PROBLEM

Statement of the Problem

The term chondromalacia is used so commonly and with such little precision with regards to the meaning of the term, that much of its value has been lost. Büdinger (1908:510) stated:

> Internal derangement will simply not disappear from the surgical literature. It is the symbol of our helplessness in regards to diagnosis and our ignorance of the pathology of a large number of joint diseases, particularly in the knee.

This statement reflects the current situation for the condition chondromalacia of the patella.

Ficat and Hungerford (1977) revealed that upon reviewing the literature they found the term to be used by anyone from a pathologist describing the physical characteristics of a bit of articular cartilage to a physiatrist describing patello-femoral arthralgia without anatomical or pathological diagnosis. Orthopaedists and general practitioners on the other hand, make their diagnoses based on the patients' complaints as well as signs and symptoms uncovered during the examinations. From this description, one can see that none of these definitions is solely representative of this condition.

Insall, Falvo and Wise (1976) stated that chondromalacia of the patella is one of the most frequently encountered causes of knee pain in the young population and yet its causes and natural history are not

fully understood. Wiles, Andrews and Devas (1956) wrote that the earliest macroscopic changes of swelling and softening of the cartilage were reported by Øwre (1936), during his post-mortem examinations, to be present in at least five out of six people by the age of thirty even though they may remain symptomless throughout life. One must, however, take into consideration that Øwre's necropsy group consisted of only one hundred and six subjects which may not be sufficient to draw conclusions in regards to the entire population.

The term chondromalacia patella has become a general one, characterized by most orthopaedic surgeons as retropatellar discomfort which is exacerbated by activities such as stair climbing or sitting in a confined space with the knee flexed for extended periods of time. Subjective complaints by the patient often include buckling, instability, locking, feeling of stiffness and swelling. Physical examination reveals retropatellar pain, which may reliably be elicited by patellar compression while the knee is slightly flexed, and joint line tenderness especially on the medial aspect of the knee which is often complicated or confused by a meniscal lesion. Other pertinent findings often disclosed are increased quadriceps angle (Q-angle), quadriceps atrophy, and knee effusion. The amount of restriction to activities helps determine the severity of the condition (Darracott, 1973; Dehaven, Dolan and Mayer, 1979; Gruber, 1979; Wiles, Andrews and Bremner, 1960).

Several authors have used the term chondromalacia to describe changes taking place on the under surface of the patella, with or without reference to clinical signs. Büdinger (1906) was the first to describe the disease as a cartilage lesion on the under surface of the patella showing softening and fissures. He attributed the disorder to a

traumatic origin and stated that diagnosis was substantiated by clinical findings. Øwre (1936) reported a study of one hundred and six cadavers examined at autopsy for cartilage changes. His report created much confusion because he used the term chondromalacia to describe solely pathological findings which meant that the term could now be regarded as describing a pathological condition as well as a clinical syndrome, and in many cases, a combination of the two.

Outerbridge (1961) classified the pathological changes in the patellar cartilage into four stages, rendering the diagnosis and assessment of disease severity possible only during inspection of the articular cartilage at surgery or on autopsy. The four classifications were as follows: Grade 1 - localized softening, and swelling of the articular cartilage; Grade 2 - fragmentation and fissuring in an area half an inch (1.3 cm) or less in diameter; Grade 3 - fragmentation and fissuring in an area more than half an inch (1.3 cm) in diameter; Grade 4 - erosion of articular cartilage down to the subchondral bone. Grades 1 and 2 represented mild to moderate pathological changes; Grades 3 and 4 represented severe chondromalacia. This classification system made no mention of clinical signs or symptoms in the assessment of disease severity.

Not only is there great controversy in the use and meaning of the term chondromalacia of the patella, but the etiology and treatment of this condition still remains a mystery in many cases. The fact that over one hundred and fifty different operative procedures have been described for the relief of chondromalacia of the patella only emphasizes that a complete understanding of the condition has still not been achieved (Knight, 1978). Causes such as trauma, generalized constitu-

tional disturbances (endocrine or toxemic conditions), abnormal patello-femoral contact due to a malalignment or an anatomical alteration, nutritional disturbance, abnormality in the patella blood supply system, and disuse, all have been postulated as reasons for the pain and cartilage disturbance. If such a variation in causes can produce similar symptoms, there should also be as many treatments. A relationship should exist between differentiation of causes and associated treatments. For example, treating the condition by strengthening the muscles around the knee joint when it has been established that the basic causative factor for the symptoms stems from gross malalignment of the skeletal components is unlikely to alleviate symptoms. However, it must be stated that although gross malalignment may exist, the knee may be asymptomatic until it becomes the target of a blow in the vicinity of the quadriceps area. This muscle then begins to atrophy due to the pain and swelling present and the malalignment begins to cause symptoms of chondromalacia. By strengthening the quadriceps muscle, it may be possible to again produce a symptomless knee.

The literature is replete with articles on chondromalacia, but as long as controversies exist as to the simple meaning of the term, disagreement will also occur as to the cause, natural history and treatment associated with this disorder. As pointed out by James (1979), the etiology of chondromalacia is likely to be multifactorial, therefore the topic should be approached in much the same way.

Objectives of the Study

The objectives of the study were to examine radiographic measurements in sixty patients having been diagnosed as having chondromalacia

of the patella.

More specifically, radiographic findings were examined for the following measurements:

a) congruence angle

b) sulcus angle

c) lateral patello-femoral angle

d) lateral patellar displacement

e) patella alta and infra by P/PT measurements

f) patella alta by A/B measurements

g) shape of patella

A second objective was to determine whether the congruence angle, the sulcus angle, the lateral patello-femoral angle and the lateral patellar displacement examined in the twenty degree x-ray view equals that observed in the forty-five degree x-ray view. These measurements were chosen to be examined in two different views because a subluxated patella may be evident with the knee in twenty degrees flexion but not in the forty-five degree knee flexion since the patella is pulled into the inter-condylar groove as the knee increases in flexion.

Research Hypotheses

Within the sample of patients diagnosed as having chondromalacia of the patella, the incidence of abnormal radiographic findings is greater than the incidence of normal radiographic findings, as reported in the literature, for the following measurements:

a) congruence angle

b) sulcus angle

c) lateral patello-femoral angle

d) lateral patella displacement

e) ratio of patella length/patella tendon length (P/PT)

f) ratio of patella tendon to tibial plateau/patella articulating surface (A/B)

g) Wiberg's Type III or Baumgartl's dysplastic patella.

The sulcus angle, congruence angle, lateral patello-femoral angle and lateral patella displacement measured in the twenty degree x-ray view are different from the measurements in the forty-five degree view.

Significance of the Study

The current problems impeding the diagnosis and treatment of chondromalacia of the patella have been discussed. The study provides a more objective means of assessing the etiology of the disorder and minimizes the reliance on the patient's subjective complaints and clinical findings, which are so common to many disorders. However, it must be emphasized that measurement of an abnormal angle does not assure a cause-effect relationship. It is well accepted that the patella is controlled by the dynamic and static elements of the extensor mechanism as well as being significantly influenced by torsional and angular alignment of the proximal and distal lower extremity segments (Merchant, Mercer, Jacobsen and Cool, 1974). Since variation of any of these factors may act as contributory causes to the disorder, the ability to quantify the extent of bony abnormalities as a contributing factor will be of great importance in determining the proper diagnosis.

The treatment instituted by most physiotherapists, in cases of chondromalacia of the patella, has mainly aimed at strengthening the quadriceps muscle group especially the vastus medialis in an effort to prevent the vastus lateralis from laterally dislocating or subluxating

the patella. With an abnormal lateral pull on the patella, a point of greater stress is created on the median ridge, between the medial and lateral facets, which leads to articular damage (Insall, Falvo and Wire, 1976; Knight, 1978). By strengthening the opposing muscle such an abnormal pull could be neutralized. However, if the reason for the abnormal tracking of the patella is a result of anatomical variations, such as observed with patella alta or with an increased Q-angle, improvement in symptoms achieved by this type of conservative treatment may be minimal. On the other hand, if such symptoms are the result of simple muscle imbalance or postural deformities, conservative treatment, such as exercise and external aids aimed at realigning the patella, could successfully spare the patient from surgical procedure. At the same time, the number of unsuccessful surgical procedures performed to correct this disorder may be decreased.

Much time and frustration could be avoided on the part of the physician and the physiotherapist, and also, psychological and physical trauma to the patient could be minimized if such information as congruence angle, sulcus angle, lateral patello-femoral angle, patella height, lateral patella displacement and patella shape were available to the practitioner when making a decision as to the type of treatment to institute. The underlying causes just outlined could either be ruled out or examined with greater precision in an attempt to make a decision as to the etiology of the disorder. The studies carried out to date have considered one or a few parameters such as: patella height (Marks and Bentley, 1978); lateral patello-femoral angle (Laurin, Levesque, Dussault, Labelle and Peides, 1978); and congruence angle (Merchant, Mercer, Jacobsen and Cool, 1974) as contributing factors in chondro-

malacia of the patella. No studies have been reported where numerous radiological measurements have been pooled together in an attempt to examine the contribution of each in the etiology of the disorder.

Definition of Terms

Chondromalacia Patella - Premature softening of the cartilage on the under surface of the patella. The diagnosis of chondromalacia is made if the following major findings are present:

- retropatellar discomfort exacerbated by stair climbing
- feeling of stiffness at the knee
- retropatellar pain that can reliably be elicited by patellar compression down onto the femoral condyles while the knee is in extension (Clark's Sign).

The following minor signs may also be present and will help to confirm the diagnosis:

- retropatellar discomfort exacerbated by sitting in a confined space with knee flexed for extended periods of time (Movie Sign)
- buckling, locking and swelling
- joint line tenderness mainly on the medial aspect of the knee
- pain on palpation of the under surface of the patella.

The condition is no longer considered to be chondromalacia but rather osteoarthrosis of the patello-femoral joint when on radiograph there is joint space narrowing, cyst formation, sclerosis or osteophyte formation.

Congruence Angle - The sulcus angle (see definition), in an anterior-posterior view of the femoral sulcus on skyline view with the

knee flexed to twenty and forty-five degrees, is bisected by a neutral reference line. The apex of the articular patellar ridge is connected to the lowest point on the sulcus. When this latter line is medial to the neutral reference line, the angle is given a negative value; when lateral, a positive value. This angle measures the relationship of the patellar articular ridge to the intercondylar sulcus. Normal value equals minus six degrees with a standard deviation of plus or minus eleven degrees (Merchant et al., 1974) (Appendix A).

Lateral Patello-Femoral Angle - Angle formed by the intersection of the line drawn between the highest point on the femoral condyles and the line drawn between the margins of the lateral facet of the patella in an anterior-posterior view of the femur on skyline view with the knee in twenty and forty-five degrees flexion. Normally, the angle opens laterally (Laurin et al., 1978) (Appendix B).

Lateral Patellar Displacement - Is assessed on an anterior-posterior view of the femur on skyline view in twenty and forty-five degrees flexion. A line originating from the summit of the medial femoral condyle is drawn perpendicular to a line joining the summits of both medial and lateral femoral condyles. In normal candidates, the medial edge of the patella is medial to the perpendicular line in ninety-seven percent of patients, and if this perpendicular line is displaced towards the intercondylar groove by one millimeter to its original landmark, it can be stated that the medial edge of the normal patella is medial to this line in all normal individuals. In chondromalacia patella, an excessive lateral patellar displacement is noted in thirty percent of the patients with a lateral patello-femoral angle being normal. In subluxating patella, if the lateral patellar displacement is excessive,

they also display an abnormal patello-femoral angle (Laurin, Dussault and Levesque, 1979) (Appendix C).

Patella Length/Patella Tendon Length (P/PT) - The ratio of the length of the patella at its greatest diagonal length, to the length of the patella tendon, measured on its posterior surface from its origin on the lower pole of the patella to its insertion into the tibial tubercle. In the present study, the measurements are made on a lateral view of the knee while in ninety degrees of flexion. The original investigators did their measurements in thirty degrees of flexion (zero degrees being full extension); however, as pointed out by Insall and Salvati (1971), since the ligamentum patellae is not elastic, the amount of knee flexion will have little effect on the patella height. The normal ratio is 1.02 with a standard deviation of plus or minus 0.13. A ratio greater than this value by two standard deviation refers to patella infra or low riding patella and a smaller ratio refers to patella alta or high riding patella (Insall and Salvati, 1971; Lancourt and Cristini, 1975; Marks and Bentley, 1978) (Appendix D).

Patella Tendon to Tibial Plateau/Patella Articulating Surface (A/B) - A ratio to determine the level of the patella in relation to the femur. This method is used when the tibial tubercle is not clearly outlined or in cases of traction apophysitis of the tibial tubercle or of the patella. In the present study, the measurements were made on a view of the lateral aspect of the knee positioned in ninety degrees of flexion. The original investigators, however, did their measurements in thirty degrees flexion (zero degrees being full extension) but as mentioned previously, due to the non-elastic nature of the ligamentum patellae, the

amount of knee flexion should have minimum effect on the height of the patellae. The normal ratio is 0.8, with a standard deviation of plus or minus 0.14 (Blackburne and Peel, 1977) (Appendix E).

Shape of the Patella - The patella has been classified into four distinct categories as illustrated in Appendix F. The first three are described as Wiberg's Type I, II, and III (Wiberg, 1941) and the fourth was described by Baumgartl (1964):

> Wiberg Type I - both medial and lateral patellar facets are gently concave, symmetrical and roughly the same size.
>
> Wiberg Type II - the medial facet is distinctly smaller than the lateral one, both facets are slightly concave as illustrated by Wiberg's diagram although he did not describe the shape of the facets in his original article.
>
> Wiberg Type III - the medial facet is considerably smaller with marked lateral predominance. Wiberg did not state that the medial facet had to be convex but his example did show this, and other authors (Merchant et al., 1974) have included medial facet convexity for Type III criteria.
>
> Baumgartl - this category is referred to as the rare type of patella. It describes a dysplastic type of patella such as a flat patella with little medial facet, or a pebble or half-moon type of patella.

Skyline View (sunset view, axial roentgenogram) - An x-ray technique used to photograph the patello-femoral joint, i.e., the anterior surface of the femoral condyle and the posterior inferior surface of the patella (Appendix G).

Sulcus Angle - Measures the depth of the intercondylar sulcus. This angle is formed by the union of the two highest points on the femoral condyle to the lowest point in the intercondylar sulcus of the femur on an anterior posterior view of the femur on skyline view in a twenty and forty-five degree knee flexion angle. Normal value equals one hundred

and forty-two degrees with a standard deviation of plus or minus six degrees (Brattstrom, 1964) (Appendix H).

Delimitations

The proposed investigation was delimited as follows:

1) Only female subjects who had been diagnosed as having chondromalacia of the patella by a group of orthopaedic surgeons at The University of Alberta Hospital, Edmonton, Alberta.

2) The subjects ranged in age from fifteen to thirty-five years of age.

3) Measurements were made from three sets of radiographs only: i) skyline view with the knee in twenty degree flexion; ii) skyline view with the knee in forty-five degree flexion; and, iii) lateral view with the knee in ninety degree flexion.

4) Measurements were confined to the first series of radiographs, if more than one series of pictures were available, to ensure that all the radiographs represented pre-operative findings.

5) The radiographic data was limited to the following measurements: a) angle of congruence at twenty degrees and forty-five degrees knee flexion; b) sulcus angle at twenty degrees and forty-five degrees knee flexion; c) lateral patello-femoral angle at twenty degrees and forty-five degrees knee flexion; d) lateral patellar displacement at twenty degrees and forty-five degrees knee flexion; e) patella/patella tendon length ratio; f) patella tendon to tibial plateau/patella articulating surface ratio; g) patella configuration.

Limitations

The limitations imposed on the study were as follows:

1) The diagnosis of the condition chondromalacia patella was dependent on the extent to which the physicians adhered to similar criteria in arriving at all diagnoses.

2) The accuracy of the radiographic measurements was limited by the ability of the investigator to correctly and consistently interpret the radiographic views. Pretesting has shown that the investigator's reliability correlates with the orthopaedic surgeons' at an r value of .977 for the sulcus angle, .957 for the congruence angle, .937 for the patella length, .990 for the patella tendon length, .950 for the patella articulation length and .986 for the tibial plateau distance. Measurements for the lateral patello-femoral angle and the lateral patellar displacement show a one hundred percent agreement between raters and for the patella configuration, a ninety percent agreement.

3) Other parameters which may have played a role in the disorder aside from variations in radiographic measurements, such as previous injuries, severity of the condition, foot and extremity alignment, patient's weight, previous surgeries, daily activities, and joint laxity were not considered.

Chapter 2

LITERATURE REVIEW

Introduction

If the term chondromalacia of the patella is to remain as part of the medical vocabulary dealing with disorders of the knee, an attempt must be made to define criteria that will help differentiate between the numerous causes of chondromalacia. James (1979) emphasized the fact that the patella is controlled by the dynamic and static elements of the extensor mechanism as well as by torsional and angular alignment of the proximal and distal lower limb segments. He further stated that these components must function in harmony for normal patello-femoral mechanics and that any alteration in this precisely tuned mechanism can initiate chondromalacia.

When dealing with chondromalacia patella, it is often the overlying symptoms that are dealt with, with very little attention directed towards the underlying defect. If by specific methods one was able to identify any anatomical or mechanical factors contributing to the symptoms, then proper measures could be initiated with a view towards correcting these defects.

Considerable research has been directed toward the area of chondromalacia of the patella, as well as the area of patella subluxation, dislocation and osteoarthritis, and their relationship to chondromalacia. However, a great deal of controversy exists as to the pathology, etiology and treatment of choice in this condition.

Historical Review

Many attempts have been made to improve the position of function of the patella. One of the earliest papers dealing with this topic was published by Roux in 1888 in Paris. This paper was followed by one by Goldthwait of Boston in 1899 who wrote an article on permanent dislocation of the patella. In 1906, Büdinger described a disorder involving cartilage lesions on the under surface of the patella showing softening and fissures. He, as well as many other authors during that time period (Aleman, 1928; Axhausen, 1922; Frund, 1926; Ludloff, 1910), based on clinical symptoms as well as surgical findings, considered trauma to be the cause of the articular cartilage rupture. König (1924) was the first to use the term chondromalacia. He also described patients suffering from patello-femoral arthralgia with a defined articular lesion of the patellar cartilage, and again attributed this to a traumatic origin. Läwen (1925) suggested that while trauma was the cause in many instances of chondromalacia, the disease could also arise without any known injury. He also stated that the disorder need not necessarily stem from one large traumatic incidence, but rather, could result from a series of small trauma. Increased strain stemming from a malalignment or malformation of bones as well as a decrease in the cartilage's ability to resist strain, due to some endogenous factors, were also cited by this author as possible contributing factors in the disease process. Hinricsson (1939) reported a study of six hundred and forty cases of chondromalacia, in which two-thirds of the patients had suffered from some form of direct trauma to the knee.

Site of Cartilage Degeneration

The specific area of cartilage degeneration on the articular surface of the patella associated with chondromalacia has been examined by many

researchers. Opinions remain divided as to whether the degeneration takes place on the medial facet proper or on the so-called odd facet, which is the most medial aspect of the medial facet, or whether the primary area of erosion is on the ridge separating the medial and lateral facet or that separating the medial and odd facet.

Townsend, Rose, Radin and Raux (1977), examining the situation from a biomechanical view, found that cartilage degeneration took place under the central-medial aspect of the patella. They also found a difference in bone formation in this area and attributed this to the usual non-weight bearing occurring at the site during flexion ranges of zero to ninety degrees since, as they pointed out, bone develops in accordance to the demands placed on it. With activities such as stair climbing and squatting, there is an increased strain created at this central-medial area, the overload and shear stresses can no longer be accommodated for and cartilage degeneration results at precisely the area outlined. The observation that the medial facet was more involved than the lateral facet was also in agreement with other authors (Goodfellow, Hungerford, and Zindel, 1976; Stougard, 1975).

Goodfellow, Hungerford, and Zindel (1976) studied the contact areas on the patella through various ranges of knee flexion and found that during the movement from extension to ninety degrees of flexion, a band of contact sweeped across the patella from the inferior pole to the superior pole, but that the odd facet made no contact. In the range of one hundred and thirty-five degrees of flexion, separate medial and lateral contact areas formed, with the medial one limited mainly to the odd facet. The authors also found that between ninety degrees and one hundred and thirty-five degrees of flexion, the patella rotated and the ridge between the

medial and odd facets was engaged by the lateral margin of the medial femoral condyle and at one point the load was borne along this crest. During autopsy observations, it was found that cartilage lesions were mainly limited to the odd facet and to the ridge separating the medial and odd facet. It was postulated that the odd facet, due to its habitual non-contact area, and the ridge, due to its being subject to high shear stress and heavy compressive loading, were both target areas for cartilage degeneration. Insall, Falvo, and Wise (1976) and Insall, Bullough, and Burstein (1979), found the ridge between the medial and lateral facet to be the area of greatest degenerative changes. These authors emphasized that this area was well suited for large compressive forces such as those found in running and jumping, but not well suited for sideways loading or shear stress encountered in stair climbing and squatting. Outerbridge (1961) considered a rim on the superior border of the medial femoral condyle to precipitate cartilage degeneration on the medial facet of the patella. As the knee was flexed from approximately fifteen degrees to thirty degrees, the patella was dragged across this rim causing a shearing stress and therefore eroding the cartilage. This rim was found to be present to a greater or lesser degree in most adult knee joints that were examined. It was also pointed out by the author that this rim could consist of either cartilage and bone, or solely of cartilage which would therefore not be visible on roentgenogram. The presence of this rim has not been found to correlate with the occurrence of chondromalacia of the patella by other authors (Meachim and Emery, 1974).

The cartilage thickness on the under surface of the patella has been the source of discussion of many authors in regards to cartilage degeneration. Ficat and Hungerford (1977) stated that the cartilage

covering of the articular surface of the patella reached four to five millimeters in thickness in its central portion and was the thickness in the body. Øwre (1936) found the greatest thickness of cartilage to occur on the medial patellar facet immediately adjoining the ridge between medial and lateral facets. He remarked that in this region the cartilage would probably receive less nutrition and, in addition to the intense pressure against the medial facet when the knee is in extension, would more likely lead to degenerative changes. Wiberg (1941) noted that the place where the patellar cartilage was thickest seemed to vary. It was not always the median ridge nor the median facet adjoining this ridge. In some instances, it was the ridge adjoining the odd facet. Whatever the area of the patella displaying the thickest cartilage, be it the medial facet, the odd facet or the ridges between facets, it would seem that this may have an effect on the nutrients capable of reaching the depth of the articular cartilage, and therefore be a potential cause of cartilage degeneration.

Patella Blood Supply

Studies on the sources of blood supply to the patella, by Bjorkström and Goldie (1980), have revealed that in chondromalacia patellae as well as in osteoarthrosis, the arterial pattern within the patella becomes disturbed and irregular, with the formation of anastomoses taking place. There appears to be an increase in arterial distribution to areas of the patella suffering from cartilage destruction. Bain (1972), on the other hand, studying the venous flow across the cortex of the proximal part of the femur in osteoarthrosis of the hip found an increase in resistance to venous flow. No conclusive evidence had yet been reported in the literature in support of an alteration in blood flow as a causative factor in

cartilage degeneration. However, as pointed out by Bjorkström and Goldie (1980), there is obviously vascular changes associated with the articular degeneration which seem to correspond in degree to the severity of cartilage destruction. Which of the two develops first, whether it be cartilage changes or vascular alterations, is still not known.

Chondromalacia Versus Osteoarthritis

The predominant area and type of cartilage degeneration has also been studied in relation to differences between osteoarthritis and chondromalacia (Dandy and Poirier, 1975; Goodfellow, Hungerford, and Woods, 1976; Gruber, 1979; Knight, 1978). Goodfellow, Hungerford, and Woods (1976) described two distinct lesions affecting the articular cartilage of the patella. The first lesion was described as surface degeneration usually found limited to the odd facet. This disorder was age dependent and was attributed to non-habitual use. It did not cause patello-femoral pain until it had progressed to exposure of bone upon an area of habitual patello-femoral contact. The process was a very slow one and seldom occasioned pain earlier than late middle-age. When it did become symptomatic, an x-ray revealed the characteristic changes of osteoarthritis of the joint. The second lesion was described as basal degeneration, which was the one typical of chondromalacia, with fasciculation of collagen in the middle and deep zones without at first affecting the surface layers. With time, even the superficial layers became involved with changes occurring in the orientation of collagen fibers. This disorder was found to occur in two main regions; one was an area about one centimeter in diameter on each side of the ridge separating the medial and odd facet of the patella, and the second area was straddling the inferior part of the central ridge which separated the medial from the lateral facet. These types of lesions

were observed to cause patello-femoral pain in the young population. Pain, as later explained by James (1979), was the result of loss of normal energy-absorbing function of the overlying articular cartilage resulting in abnormal forces being applied to the subchondral bone which was richly supplied by pain fibers. The authors further stated that chondromalacia was not a precursor to osteoarthritis. This statement was also supported by numerous other authors (Abernethy, Townsend, Rose, and Radin, 1978; Gruber, 1979; Insall, Falvo, and Wise, 1976; Karlson, 1947; Øwre, 1936) who were in agreement that chondromalacia developed as a result of microtrauma in the region of the ridge between facets which was predisposed to degenerative changes because of heavy loading and shear stress occurring when the patella glided over the trochlea in acute flexion.

Darracott and Vernon-Roberts (1971) described the changes associated with chondromalacia patella in a slightly different manner. They listed the initial changes as occurring in the subchondral bone characterized by hyperplasia of the chondrocyte which then led to vascularization and ossification taking place in the deep zone of articular cartilage accompanied by formation of new bone and either focal or diffuse osteoporosis in trabecular bone. They noted that the involvement of the subchondral bone in this manner would explain the pain associated with the disorder.

Chondromalacia Patella and Dislocating or Subluxating Patella

Literature now confirms the close relationship between dislocating and subluxating patella and chondromalacia patella. Dandy and Poirier (1975) reported that recurrent dislocation of the patella was associated with chondromalacia of the patella in sixty-two percent of

the cases they observed and was even higher in cases of subluxating patella, where chondromalacia was found in ninety-three percent of these cases. The authors also stated that patients who had symptoms of chondromalacia as well as patella instability could expect to derive considerable benefit from realignment of the extensor mechanism of the knee, without shaving or drilling of the patella. This result was attributed to the decrease in abnormal shear stresses on the articular cartilage (Dandy and Poirier, 1975). Crosby and Insall (1976) also pointed to the high incidence of recurrent dislocation of the patella and associated chondromalacia, and reported that the most frequent technical defect was insufficient correction of the patella alta.

McKeever (1954) closely associated chondromalacia with recurrent displacement of the patella. He believed that displacement of the patella was a mechanical problem that stemmed from a weak vastus medialis muscle or a high placement of the patella, or to a poorly developed lateral femoral condyle. With a high riding patella, which he stated was usual in cases of chondromalacia, there was no constant contact with the opposed cartilaginous surface. The patella therefore remained of inferior quality and was not as resistant to its traumatic passing over the articular margin of the femur into the intercondylar groove. Variations in the stress line, caused by an increased Q-angle, altered the growth of the femoral condyle and could therefore display an increased sulcus angle with a tendency towards lateral dislocation of the patella. Recurrent dislocation could lead to degenerative changes in the articular cartilage underlying the patella.

Radiographic Assessments

Patella configuration. Wiberg (1941) described three types of

patella (see Appendix F) associated with a series of normal and pathological knees that he examined. Type I consisted of a medial and lateral facet of equal size with both facets gently concave. Type II demonstrated a lateral facet slightly larger than the medial one, both facets were slightly concave as illustrated by Wiberg's diagram although he did not describe the shape of the facets in his original article. Type III displayed a characteristically small medial facet with marked lateral predominance. Wiberg did not state that the medial facet had to be convex but his example did show this, and other authors (Merchant et al., 1974) have included medial facet convexity for Type III criteria. Wiberg (1941) associated Type III patella with chondromalacia, but was not able to conclusively demonstrate this. Furthermore, it has not been demonstrated by other authors (Hungerford and Cockin, 1975; Insall, Falvo, and Wise, 1976). Type III patella, with its small medial facet, however, has been strongly associated with recurrent dislocation of the patella (Cross and Waldrop, 1975; Ficat and Hungerford, 1977; Sifverskiöld, 1938). As the ridge between the facets is anatomically located more medially, it must still articulate with the groove between the femoral condyles. Consequently, the patella must be positioned more laterally in such patients. Baumgartl (1964) described three additional patella configurations which were, to a large extent, variations of Wiberg's Type III: A Type II/III with a smaller, flat medial facet; a Type IV displaying a very small or nearly vertical medial facet; and the Hunter's cap which basically had an absence of median ridge. Type I was said to exist in approximately eleven percent of the population, and in association with Type II, made up sixty-six percent of the population. These two types were considered to be normally shaped and able to distribute the compressive forces at the patello-

femoral joint in an even manner over the contact surface of the patella. In the remaining types of patella, the smaller medial facet would have to support a larger load per area resulting in an overload on the articular cartilage of this facet which could lead to degenerative changes. Baumgartl (1964) went on to say that thirty-four percent of all people fall within these last types with an eighty percent probability of developing patello-femoral problems. James (1979) stated that his clinical findings did not support the statement made by Baumgartl (1964) where there was an eighty percent probability of developing patello-femoral problems in these people.

Patella height. Many investigators have commented on the relationship between the height of the patella and its association to chondromalacia. Various techniques have been described in the literature to determine the position of the patella. Boon-Itt (1930) devised a formula to evaluate the level of the patella. This method proved to be very accurate, but much too complicated for practical use.

Blumensaat (1938) reported another way of determining the height of the patella by drawing a line through the femoral condyle; however, two problems arose with this method. Firstly, the knee had to be flexed precisely to thirty degrees and secondly, there was considerable inaccuracy in the technique as was demonstrated on examining normal knees (Insall and Salvatti, 1971; Lancourt and Cristini, 1975; Marks and Bentley, 1978).

A third method, devised by Insall and Salvati (1971) and also used by Lancourt and Cristini (1975), proved to be simpler and much more practical. The measurements were expressed as a ratio of the patella length to the patella tendon length. These authors found the average ratio to be 1.02 with a standard deviation of 0.13, and chondromalacia of

the patella to exhibit a smaller ratio than normal, i.e., 0.86 which was statistically significant at the 0.05 level. The interpretation was that for chondromalacia of the patella, the patella was abnormally high or patella alta. Although a similar ratio associated with chondromalacia was not found by Marks and Bentley (1978), using the same method on women with mild symptoms, they did report it was observed in those displaying severe chondromalacia. Attention must be made when interpreting the results of these last authors since their female chondromalacic group consisted of only thirty-four subjects, eighteen of whom were classified as having mild chondromalacia and sixteen of whom were listed as having severe chondromalacia. With such a limited population, very little data is available to allow the making of inferences to the chondromalacic population at large.

Significant positive correlations were also found between patella dislocation and high riding patella or patella alta (Insall and Salvati, 1971; Lancourt and Cristini, 1975). The concept of a low riding patella (patella infra) in the development of chondromalacia may well be appreciated if one accepts the malalignment factor in the etiology of the syndrome (Lancourt and Cristini, 1975). James (1979) also commented on the association between patella infra, and chondromalacia. He stated that reversal of the ratio was not only due to a relatively short patellar tendon, but may also have been due to an increased length of the patella which could have been related to increased tension in the extensor mechanism. Knight (1978) expanded on the fact that during knee flexion from zero degrees to forty-five degrees, the patello-femoral force was borne by the patella articular surface alone and was approximately equal to body weight. With greater degrees of flexion, the force was distributed between the patella and the quadriceps tendon and was now approximately four times body weight, at

sixty degrees of flexion. If the patella were abnormally high, such as in patella alta, then the patella would experience patello-femoral pressure for an increased period of time before the load could be shared by the patella tendon. The articular surfaces would also experience incongruent opposing surfaces all leading to abnormal stress on the patellar cartilage which could produce degenerative changes.

Blackburne and Peel (1977) described an alternate method of determining the height of the patella. They felt their method had greater advantages in cases where the tibial tubercle was not clearly demarcated, or in cases of Osgood-Schlatter or Larsen-Johansson disease where the apophysitis of the tubercle of the tibia or of the patella was fragmented or elongated. Their method involved determining the ratio between the perpendicular height of the lower end of the articular surface of the patella from the tibial plateau to the length of the articular surface of the patella. The normal value being 0.8 was clearly differentiated from a patella alta ratio of 1.0 or greater. They found that in cases of subluxating patella, the ratio had a value at the upper end of the range of normal, whereas in chondromalacia, the male displayed a ratio value lower than normal, but the female showed normal values.

Other measurement variations reported to be associated with chondromalacia of the patella, in addition to the patella height, was an increase in the clinical measurement of the Q-angle. Insall (1979) and Insall, Falvo and Wise (1976) reported that patella alta or increases in Q-angle were observed in most cases of chondromalacia of the patella and were considered to be the usual causes of the disorder. They also stated that it was believed that trauma either direct, such as a blow to the knee, or indirect, due to malalignment or twisting motions, were the causes of chondromalacia of the patella.

Sulcus angle and congruence angle. Merchant et al. (1974) reported that the depth of the intercondylar sulcus, which was measured by the sulcus angle, was the most important factor in distal femoral dysplasia in patients reporting recurrent dislocation of the patella. They also stated that the height of the lateral femoral condyle was only significant as it related to the depth of the sulcus, which was found to measure one hundred and thirty-eight degrees with a standard deviation of six degrees in normals. From the sulcus angle, they estimated values for the congruence angle which indicated the relationship of the patella to the intercondylar sulcus. The average value for normals was minus six degrees with a standard deviation of eleven degrees. With this angle value they could assess minor degrees of subluxation, which was not possible to do prior to this study. They found the average congruence angle of the dislocated patella to be plus twenty-three degrees which was beyond the ninety-five percentile for normals. The authors remarked that the congruence angle as a measurement of patello-femoral joint congruence was only one factor in the total evaluation of the extensor mechanism of the knee. There are many factors involved in malalignment and pathology of the patello-femoral joint and each factor must be carefully assessed.

Lateral patello-femoral angle. Laurin et al. (1979) devised three other measurement techniques to assess the patello-femoral joint relationship. The first method was referred to as the lateral patello-femoral angle reading and could easily be assessed on tangential x-ray view of the knee joint. Their findings indicated that in normals the angle opened laterally in ninety-seven percent of the cases. However, in all thirty cases of subluxating patella that were studied, the angle was observed to be abnormal, either opening medially, forty percent, or

showing no angle at all with the lines being parallel, sixty percent. The authors pointed out that since their technique has been standardized, they have not seen a subluxating patella with a lateral patello-femoral angle opening laterally. No such definite findings were found in cases of chondromalacia. In the cases of the subluxating patella, after surgical intervention had been performed, the lateral patello-femoral angles all opened laterally just as was seen in normals. The authors stated that in cases where the lines were parallel and no clinical symptoms were present, it seemed likely that the knee could be a candidate for subluxation at a later date or perhaps eventually for chondromalacia of the patella.

Patello-femoral index. The second method was called the patello-femoral index reading, and again was assessed on tangential x-ray view of the knee joint. This index was the ratio between the thickness of the medial patello-femoral interspace and that of the lateral patello-femoral interspace. These interspaces corresponded to the shortest distance between the patella facets and the articular surface of the femoral condyles. Their findings revealed that in one hundred normal subjects, the medial patello-femoral interspace was either equal to or slightly larger than that of the lateral patello-femoral interspace. The ratio had a value of 1.6 or less. In their chondromalacia group, on the other hand, ninety-three out of one hundred individuals had a patello-femoral index which was greater than 1.6. The authors explained this abnormal index in ninety-three percent of chondromalacia patients to be due to a mini-tilt of the patella with relative widening of the medial interspace.

Lateral patellar displacement. The third method, outlined by Laurin and associates (1979) was the lateral patellar displacement which

once again was assessed on a tangential x-ray view. The authors found the medial edge of the patella to lie medial to a perpendicular line erected from the medial femoral condyle in ninety-seven percent of normal individuals. Furthermore, if this perpendicular line was displaced towards the intercondylar groove by one millimeter, all normal cases showed the medial side of the patella lying medial to this line. In cases of chondromalacia of the patella, an excessive lateral patellar displacement was noted in thirty percent of the patients. Chondromalacia patellae could be distinguished from subluxating patellae in that the latter group in addition to the excessive lateral patellar displacement, also displayed an abnormal lateral patella angle which was not seen in the chondromalacia group.

Conclusion

Dehaven et al. (1979) demonstrated that conservative treatments of chondromalacia of the patella were effective in controlling the symptoms of the disorder in a great many cases. However, eighteen percent still required surgery after having undergone extensive rehabilitation. Bentley (1970) reported even larger figures - thirty-five percent - that required surgical intervention in spite of adequate conservative management. He also stated that the choice of the best procedure was difficult. Many methods of treatment have been proposed, but none have been universally successful. Some procedures have proven to be successful for some patients but not for others. The reason for such diversity in results may stem from the fact that the underlying etiology is very different in the various patients.

An objective means of assessing these differences would be of great help in planning proper treatments for these patients. Hughston

(1968) remarked that roentgenographically, the patella and lateral femoral condyle were the most frequent areas of abnormality in recurrent subluxation of the patella. As was emphasized throughout the literature review, there appears to be a strong relationship between subluxating and dislocating patella, and chondromalacia of the patella. Therefore, the radiological description of the chondromalacic knee may help to relate particular measurements to the etiology of the disorder. Malalignment caused by such abnormalities as internal hip rotation and pronated feet may demonstrate a patella alta or an abnormally displaced patella (James, 1979) which would be detected on the radiographic measurements and then proper treatment could be instituted to correct the malalignment.

Chapter 3

METHODS AND PROCEDURES

Experimental Procedure

A retrospective evaluation was conducted using the records of sixty female patients clinically diagnosed as having chondromalacia of the patella, by a group of orthopaedic surgeons at The University of Alberta Hospital (Edmonton, Alberta), between 1974 and 1981. Patients were considered to have chondromalacia patella if they presented with the following major signs: retropatellar discomfort exacerbated by stair climbing; feeling of stiffness at the knee; and, retropatellar pain that could reliably be elicited by patellar compression onto the femoral condyles while the knee was fully extended. Certain minor signs may or may not have been present but if so, were an aid in making a more positive diagnosis. These signs included: retropatellar discomfort exacerbated by sitting in a confined space with the knee flexed for extended periods of time; buckling, locking and swelling; joint line tenderness mainly on the medial aspect of the knee; and, pain on palpation of the undersurface of the patella. In association with pain, grating could often be felt while performing these manoeuvres. The general condition of the subjects was good except for the problem associated with their chondromalacic knee. The subjects ranged in age from fifteen to thirty-five years.

The sample was selected from a compiled list of patients with chondromalacia patella having been seen by the above-mentioned group of

orthopaedic surgeons. The criteria for inclusion in the study were: that the patient be a female, be in the correct age range, and have accessible roentgenograms.

All measurements were made by the author. The radiographs were displayed on a portable viewbox with a plastic sheet placed over each and secured in place with paper clips. A special wax pencil, Staedler Film-Marker 108-3, was used to mark anatomical landmarks on the plastic sheet. This sheet was then removed once the measurements were recorded. The use of the plastic sheet allowed another investigator, an orthopaedic surgeon, to randomly recheck the measurements to test the reliability of the author's measurements. All measurements were done using a small plastic goniometer, accurate to the nearest five degrees; and a ruler expressed in centimeters. All readings were recorded on a Data Acquisition Form (Appendix I) for each subject.

The following three radiographic views were examined for each patient: tangential views at twenty degrees (Plate 1) and forty-five degrees of flexion of the knee (Plate 2), and a ninety degree flexion in the lateral plane (Plate 3). Seven parameters were evaluated in each knee (Figure 1):

1. the sulcus angle at twenty degrees and forty-five degrees of knee flexion as described by Brattstrom (1964) (Appendix H).
2. the congruence angle at twenty degrees and forty-five degrees of flexion as described by Merchant et al. (1974) (Appendix A).
3. the lateral patello-femoral angle at twenty degrees and forty-five degrees of knee flexion as defined by Laurin, Levesque, Dussault, Labelle and Peides (1978) (Appendix B).
4. the lateral patellar displacement as outlined by Laurin,

Plate 1. Tangential view of twenty degrees knee flexion.

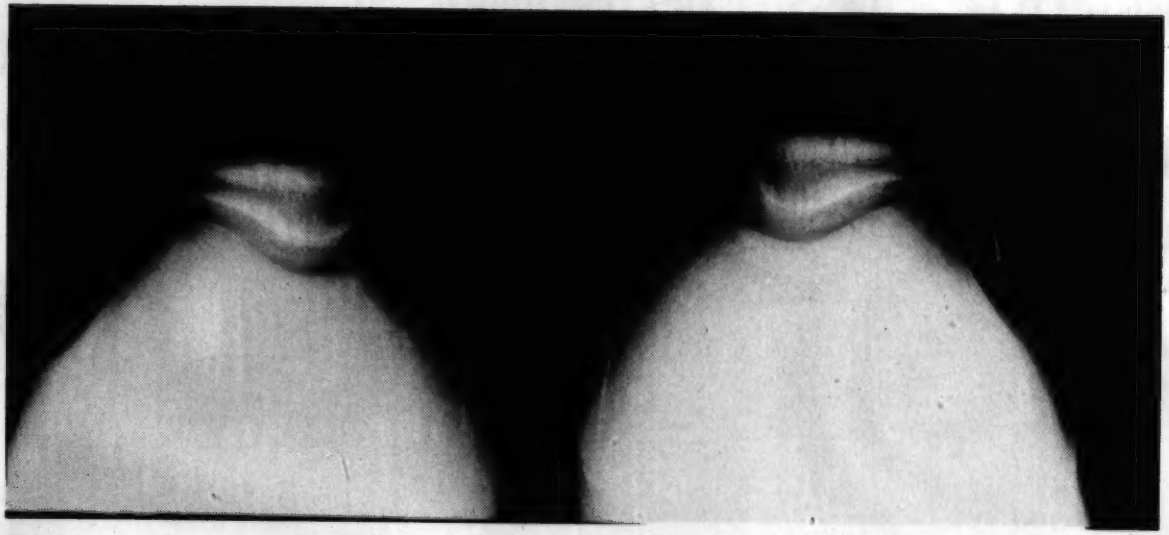

Plate 2. Tangential view of forty-five degrees knee flexion.

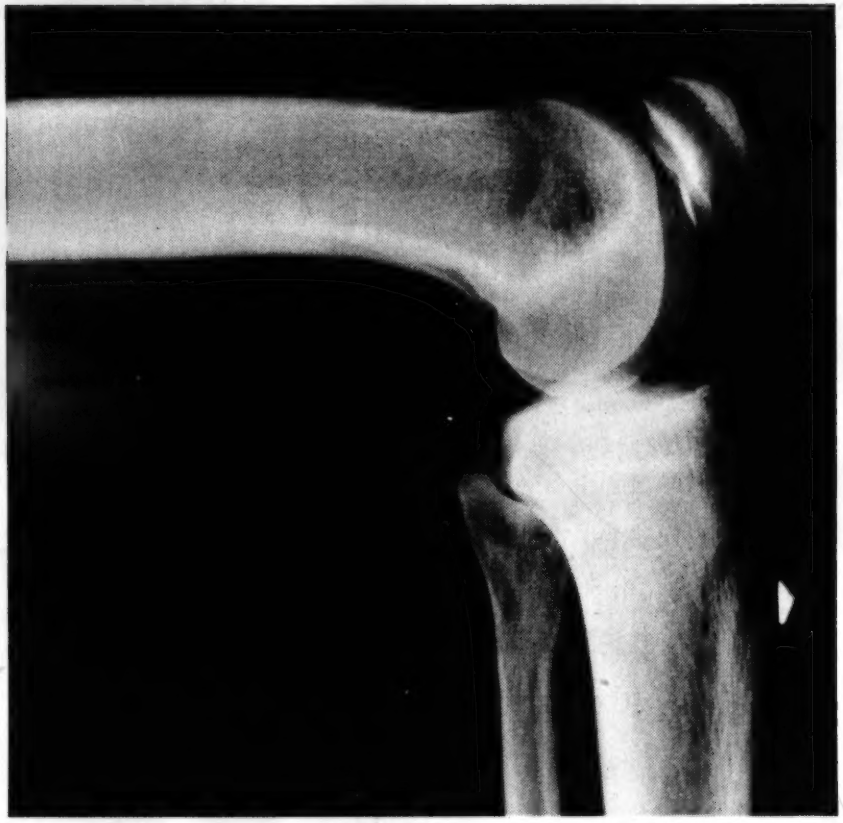

Plate 3. Lateral view of ninety degrees knee flexion.

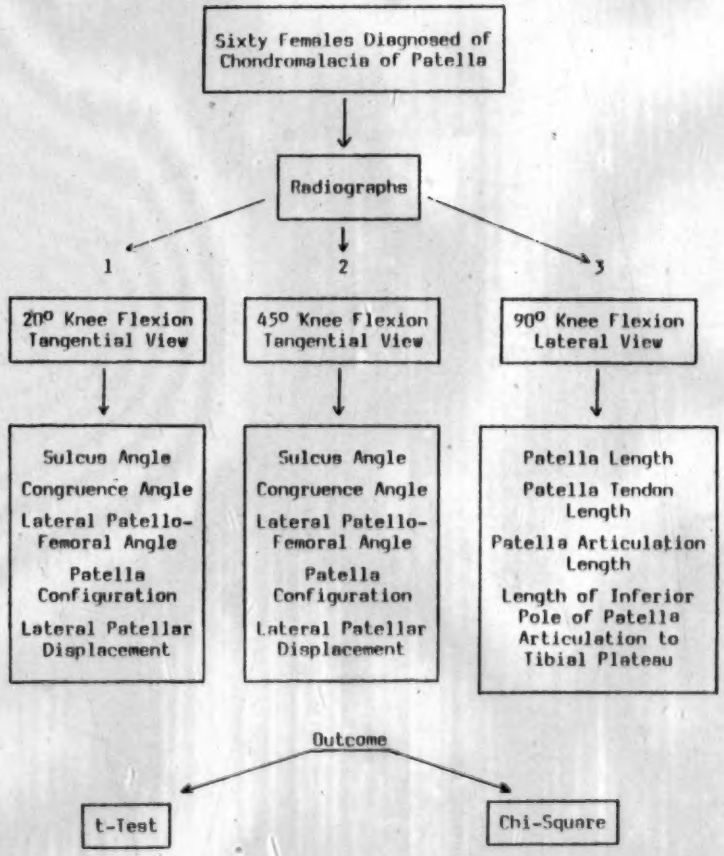

Figure 1. Flow diagram of study being conducted.

Dussault and Levesque (1979) (Appendix E).

5. the presence of patella alta or infra as measured on a lateral roentgenogram by the method of Insall and Salvati (1971) (Appendix C).
6. the patella level (A/B) ratio as outlined by Blackburne and Peel (1977) (Appendix D).
7. the configuration of the patella was determined using the classifications outlined by Wiberg (1941) and Baumgartl (1964) (Appendix F).

Data Presentation and Analysis

The data collected for each subject was recorded on a Data Acquisition Form (Appendix I).

For all seven measurements, congruence angle, sulcus angle, lateral patello-femoral angle, lateral patella displacement, P/PT ratio, A/B Ratio and patella configuration, the number of normal measurements were compared to the number of abnormal measurements using a one-way Chi-square test with nominal data. The .05 level of significance was adopted. A Chi-square test was chosen to analyse the data since normal values had previously been established in the literature (Ferguson, 1976) and the investigator was simply concerned with the frequency of abnormal versus normal values in the group under investigation.

The criterions for normality were based on values falling within the ranges reported in the literature for normal populations. In all cases, except lateral patello-femoral angle, lateral patellar displacement and patella configuration, normal measurements were defined as being within two standard deviations of the mean for the normal populations since these values were stated, by the different authors, to represent their normal

groups. All values falling beyond two standard deviations were considered abnormal. In the lateral patello-femoral angle, lateral patellar displacement and patella configuration, specific criterions for normality were followed as outlined in the Appendices B, C, and F. To ensure that the population examined in the present study was similar, in all aspects, to the normal populations described in the literature, except for the variable under study, all authors were individually contacted by letter to obtain specific population description (Appendix J). Within a very narrow margin of difference, all populations were representative of the population under study as far as the author could assess from the information received. The data was presented in the following manner for all measurements:

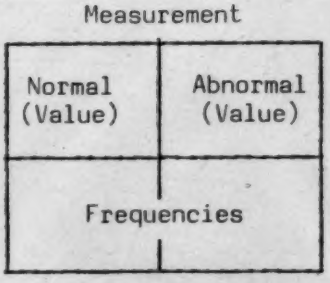

Figure 2. Method of data presentation.

Values for the congruence angle, and the sulcus angle, at twenty degrees knee flexion were compared to those found at forty-five degrees using a t-test for correlated samples. The .05 level of significance was adopted. The values for the lateral patello-femoral angle and the lateral patellar displacement at twenty degrees knee flexion were compared to those found at forty-five degrees using a test for differences between proportions for correlated samples. The .05 level of significance was again adopted.

In order to ensure the reliability of the investigator's measurements, as mentioned previously, another investigator randomly rechecked the measurements. Pearson Product Moment Correlation Coefficients were performed and the following correlation values were obtained: .977 for the sulcus angle; .957 for the congruence angle; .937 for the patella length; .990 for the patella tendon length; .950 for the patella articulation length; and, .986 for the tibial plateau distance. These correlation values proved to be significant at the .001 level. Measurement for the lateral patello-femoral angle and lateral patellar displacement showed a one hundred percent agreement between raters, whereas determination of the patella configuration showed a ninety percent agreement (Appendix K).

Chapter 4

RESULTS

The knee roentgenograms of sixty female patients diagnosed as having chondromalacia of the patella were evaluated. The purpose of the study was to determine whether diagnosed chondromalacia patients had increased frequency of abnormal radiographic measurements representing the alignment of the patello-femoral joint complex. Seven measurements were taken for each subject with four of the measurements being repeated on two radiographic views; a twenty degree tangential view and a forty-five degree tangential view. It was not possible to obtain all measurements for all patients due either to poor radiographic quality of the existing film or to the unavailability of the required films.

The results obtained from the current study refer to seven main areas. Measurements of the sulcus angle, the congruence angle, the lateral patello-femoral angle and the lateral patellar displacement were done on forty-seven patients with the knee in twenty degrees flexion, and on sixty patients with the knee in forty-five degrees flexion. The height of the patella was evaluated on fifty-five patients using two methods; the P/PT ratio and the A/B ratio. Lastly, the patella configuration was determined for all sixty patients on the forty-five degree tangential radiographic view. The raw data for all measurements are found in Appendix L.

Sulcus Angle

Values for the sulcus angle at twenty and forty-five degrees knee flexion are shown in Table 1. These figures represent the frequency of abnormal versus normal measurements on the sulcus angle, as defined by Brattstrom (1964). A Chi-square test for nominal data was performed and resulted in a significant difference at the .001 level between the abnormal and normal measurements on both the twenty and forty-five degree views (Table 2). A significant difference existed between the chondromalacia group and the normal population in regards to measurements on the sulcus angle.

Table 1

Frequency of Normal Versus Abnormal Measurements on the Sulcus Angle in (a) Twenty Degrees Tangential View on X-Ray Film, and (b) Forty-Five Degrees Tangential View on X-Ray Film

	Normal Measurement (130^{o} - 154^{o})	Abnormal Measurement ($<130^{o}$, $>154^{o}$)
(a)	33	14
(b)	40	20

A t-test for correlated samples was performed to test the significance between the sulcus angle in the twenty degree knee flexion view versus the forty-five degree view (Table 3). Results showed a significant difference at the .02 level for the left knee and at the .01 level for the right knee. This data indicates that the knee position at twenty and forty-five degrees has a significant effect on the depth of the inter-

Table 2

Chi-Square Values in Twenty and Forty-Five Degree Views on X-Ray Film for (a) Sulcus Angle, (b) Congruence Angle, (c) Lateral Patello-Femoral Angle and (d) Lateral Patellar Displacement; in the Ninety Degree View on X-Ray Film for (e) P/PT Ratio, (f) A/B Ratio; and in the Forty-Five Degree View on X-Ray Film for (g) Patella Configuration

	Measurement	Radiographic View	Degrees of Freedom	Chi-Square	Probability
(a)	Sulcus Angle	Twenty degree tangential	1	60.79	p<.001
		Forty-five degree tangential	1	101.40	p<.001
(b)	Congruence Angle	Twenty degree tangential	1	5.97	p<.02
		Forty-five degree tangential	1	17.19	p<.001
(c)	Lateral Patello-Femoral Angle	Twenty degree tangential	1	3.15	p<.01
		Forty-five degree tangential	1	22.46	p<.001
(d)	Lateral Patellar Displacement	Twenty degree tangential	1	71.68	p<.001
		Forty-five degree tangential	1	78.95	p<.001
(e)	P/PT Ratio	Ninety degree lateral	1	40.22	p<.001
(f)	A/B Ratio	Ninety degree lateral	1	10.55	p<.01
(g)	Patella Configuration	Forty-five degree tangential	1	47.02	p<.001

Table 3

Significance Test for Differences Between the Twenty Degree and Forty-Five Degree Tangential Views on X-Ray Film for the Left and Right Knee on (a) Sulcus Angle, (b) Congruence Angle, (c) Lateral Patello-Femoral Angle, and (d) Lateral Patellar Displacement

	Measurement	Statistical Test Utilized	Test Value	Probability
(a)	Sulcus Angle - left	t-test for correlated samples	t = 2.53	p<.02
	Sulcus Angle - right	t-test for correlated samples	t = 3.15	p<.01
(b)	Congruence Angle - left	t-test for correlated samples	t = .340	p>.20
	Congruence Angle - right	t-test for correlated samples	t = .293	p>.20
(c)	Lateral Patello-Femoral Angle - left	Z-test for difference between proportions for correlated samples	Z = .447	p>.05
	Lateral Patello-Femoral Angle - right	Z-test for difference between proportions for correlated samples	Z = 1.0	p>.05
(d)	Lateral Patellar Displacement - left	Z-test for difference between proportions for correlated samples	Z = .33	p>.05
	Lateral Patellar Displacement - right	Z-test for difference between proportions for correlated samples	Z = 1.41	p>.05

condylar groove.

Congruence Angle

The values for the congruence angle at twenty and forty-five degrees knee flexion are shown in Table 4. These values represent the frequency of abnormal versus normal measurements on the congruence angle as defined by Merchant, Mercer, Jacobsen, and Cool (1974). A Chi-square test for nominal data was performed and showed a significant difference at the .02 level on the twenty degree view, and at the .001 level on the forty-five degree view between the abnormal and normal measurements (Table 2). A significant difference exists with regard to the congruence angle measurements, between the chondromalacia group and the normal population.

Table 4

Frequency of Normal Versus Abnormal Measurements on the Congruence Angle in (a) Twenty Degrees Tangential View on X-Ray Film, and (b) Forty-Five Degrees Tangential View on X-Ray Film

	Normal Measurement (-28^{o} to $+16^{o}$)	Abnormal Measurement ($<-28^{o}$, $>+16^{o}$)
(a)	41	6
(b)	50	10

Testing the significance of the congruence angle in the twenty degree knee flexion view versus the forty-five degree view using a t-test for correlated samples resulted in a non-significant difference at the .05 level, for both left and right knees (Table 3). The findings

indicate that the ranges of knee flexion examined in this study had no effect on the position of the patella in the intercondylar groove.

Lateral Patello-Femoral Angle

Table 5 shows the frequency of normal versus abnormal measurements on the lateral patello-femoral angle as described by Laurin, Levesque, Dussault, Labelle and Peides (1978). A Chi-square test for nominal data was performed and showed a significant difference between the normal and abnormal measurements on the lateral patello-femoral angle at the .01 level, for the twenty degree view and at the .001 level for the forty-five degree view (Table 2). Therefore, a significant difference exists with regard to the lateral patello-femoral angle, between the chondromalacia group and the normal population.

Table 5

Frequency of Normal Versus Abnormal Measurements on the Lateral Patello-Femoral Angle in (a) Twenty Degree Tangential View on X-Ray Film, and (b) Forty-Five Degree Tangential View on X-Ray Film

	Normal Measurement (Positive)	Abnormal Measurement (Negative)
(a)	42	5
(b)	49	11

A Z-test for difference between proportions for correlated samples was performed to test the significance of difference of the lateral

patello-femoral angle in the twenty degree view versus the forty-five degree view. The test found the differences in angle between the two views to be non-significant at the .05 level for both left and right knees (Table 3). The implication of these findings point to the lack of knee flexion effect at twenty degrees and forty-five degrees on the lateral patello-femoral angle.

Lateral Patellar Displacement

Table 6 shows the frequency of normal versus abnormal values on the lateral patellar displacement measures as described by Laurin et al. (1979). A Chi-square test for nominal data showed a difference between the chondromalacia group and the normal population significant at the .001 level for both the twenty and forty-five degree views (Table 2). These findings indicate that a significant difference exists between patients with chondromalacia of the patella and the normal population with regards to the lateral patellar displacement.

Table 6

Frequency of Normal Versus Abnormal Measurements on the Lateral Patellar Displacement in (a) Twenty Degree Tangential View on X-Ray Film, and (b) Forty-Five Degree Tangential View on X-Ray Film

	Normal Measurement (Negative)	Abnormal Measurement (Positive)
(a)	32	15
(b)	42	18

A Z-test for difference in proportion for correlated samples was performed to check the significance of the twenty degree and forty-five degree knee flexion view on the lateral patellar displacement, and was found to be non-significant at the .05 level on both the left and right side of the body (Table 3). The findings demonstrate the lack of influence of knee flexion at twenty degrees and forty-five degrees on the lateral patellar displacement.

Patella Length/Patella Tendon Length Ratio (P/PT)

Table 7 outlines the number of normal versus abnormal values on the P/PT ratio, as described by Insall and Salvati (1971), in patients diagnosed as having chondromalacia of the patella. A Chi-square test for nominal data was performed and was found to be significant at the .001 level. This emphasizes the difference that exists between the chondromalacia patients and the control subjects with regard to the height of the patella.

Table 7

Frequency of Normal Versus Abnormal Measurements on the Patella Length/Patella Tendon Length Ratio (P/PT) as Measured on a Lateral X-Ray View of the Knee at Ninety Degrees Flexion

Normal Measurement (.76 to 1.28)	Abnormal Measurement (<.76, >1.28)
42	13

Tibial Plateau Distance/Patella Articulation Surface Length Ratio (A/B)

Table 8 shows the frequency of normal versus abnormal measures on the A/B ratio, as outlined by Blackburne and Peel (1977), in the group under investigation. A Chi-square test for nominal data was found to be significant at the .01 level. This finding again emphasizes the difference in the level of the patella between the normal population and patients having been diagnosed as having chondromalacia of the patella.

Table 8

Frequency of Normal Versus Abnormal Measurements on the Tibial Plateau Distance/Patella Articulation Length Ratio (A/B) as Measured on a Lateral X-Ray View of the Knee at Ninety Degrees Flexion

Normal Measurement (.54 to 1.06)	Abnormal Measurement (<.54, >1.06)
47	8

Patella Configuration

Table 9 indicates the number of normal versus abnormal patella types as outlined by Wiberg (1941) and Baumgartl (1964), in the group of chondromalacia of the patella under study. A Chi-square test for nominal data was used to test the significance of the difference in patella configuration, and was found to be significant at the .001 level. The findings indicate a predominance of Wiberg Type III patella and Baumgartl dysplastic type of patella amongst chondromalacia of the

patella patients, which is not in agreement with Wiberg's observation of a non-specific type of patella in the chondromalacia of the patella population (Wiberg, 1941).

Table 9

Frequency of Normal Versus Abnormal Patella Configurations as Determined on a Forty-Five Degree Tangential View on X-Ray Film

Normal Type (Wiberg Type I or Type II)	Abnormal Type (Wiberg Type III or Baumgartl Type)
22	38

Chapter 5

DISCUSSION

The purpose of the present study was to examine the relationship between selected radiographic measurements, namely sulcus angle, congruence angle, lateral patello-femoral angle, lateral patellar displacement, patella length/patella tendon length ratio, tibial plateau distance/patella articular surface length ratio and patella configuration (Figure 1) to chondromalacia of the patella. Frequencies of normal versus abnormal measurements in the chondromalacia group were compared to the frequencies reported, by previous authors, on normal populations. It was also the intent of the author to see whether knee flexion at twenty degrees (zero degrees being full extension) had a different effect on patella alignment compared to the forty-five degrees knee flexion view.

Sulcus Angle

Measurements of the sulcus angle showed a statistically significant difference between the frequency of normal versus abnormal measurements in the chondromalacia group on both the twenty and forty-five degrees knee flexion views. Measurement of sulcus angle on chondromalacia patients have not, to the author's knowledge, been reported in the literature; however, studies have reported measures of the sulcus angle on patients suffering from recurrent dislocation of the patella (Brattström, 1964). Brattström (1964) found that the most important factor in distal femoral

dysplasia, in patients with recurrent dislocation of the patella, was the depth of the intercondylar sulcus, as measured by the sulcus angle. Measurements of the sulcus angle in the recurrent dislocating group were found to be significantly different from the normal population. Review of the literature has shown the close association between chondromalacia patella and patella dislocation and subluxation (Crosby and Insall, 1976; Dandy and Poirier, 1975; Newberg and Seligson, 1981). No medical histories were available for any of the patients investigated in the present study. Therefore, patella subluxation or dislocation could have been a common occurrence in addition to the chondromalacia patella. The altered sulcus angle may have created a malalignment problem resulting in patella dislocation. This traumatic dislocation or simply subluxation would then cause an abnormally high shear stress on part of the articular cartilage resulting in degenerative changes. Results did not show any preponderance for the abnormal sulcus angle to be larger or smaller than normal, both occurred with approximately the same frequency.

When the number of abnormal sulcus angles at twenty degrees knee flexion were compared to those found at forty-five degrees knee flexion, a statistically significant difference was found between the two views, with a greater number of abnormal measurements found in the forty-five degree view. The reason for the difference in sulcus angle between the two views is not clear, nor does it agree with Merchant, Mercer, Jacobsen and Cool's (1974) observation of no changes in the intercondylar sulcus shape through the range of thirty degrees to ninety degrees of knee flexion on normals. The twenty degree view observed in the present study was smaller than that observed by the latter authors, and it may be that the twenty degree view showed abnormalities which are not seen on any of

the views between thirty and ninety degrees. The differences found in the present study may also have stemmed from a true difference existing between the chondromalacia group and the normal population with regards to the depth of the intercondylar sulcus or may simply have been due to an error in patient positioning during the taking of the x-ray, with the legs being rotated therefore resulting in an altered sulcus angle.

Congruence Angle

Values for the congruence angle at twenty and forty-five degrees knee flexion showed a statistically significant difference in the frequency of normal versus abnormal measurement in the chondromalacia group. Values for the congruence angle in chondromalacia patients have not been reported in the literature, however, just as with the sulcus angle, abnormal values have been shown to exist in patients with recurrent dislocation of the patella. Merchant, Mercer, Jacobsen and Cool (1974) have reported an average congruence angle of plus twenty-three degrees in a group of twenty-five recurrent dislocating knees compared to minus six degrees for the normal knees. Again, if one accepts the theory of chondromalacia patella as stemming from abnormal stresses placed on the articular cartilage, an abnormal congruence angle resulting in the patella articulating surface no longer being congruent with the reciprocal femoral intercondylar sulcus, may easily explain the cartilage changes seen with this disorder.

Comparison of the congruence angle at twenty degrees knee flexion versus forty-five degrees knee flexion resulted in a non-significant difference between the two views. These findings are in agreement with Merchant, Mercer, Jacobsen and Cool (1974) who found no significant change in the relationship of the patella to the sulcus through the range

of thirty to ninety degrees knee flexion in a pilot group of the ten normal subjects. The findings are, however, not in agreement with the proposed hypothesis. At twenty degrees knee flexion, the patella has a greater ability to dislocate laterally than it does at forty-five degrees flexion, where it is now being pulled into the intercondylar groove by the quadriceps tendon (Laurin, Dussault, Levesque, 1979; Hughston, 1968). Due to the close relationship between patella dislocation and chondromalacia patella, it was anticipated that a greater frequency of abnormal congruence angle would be found in the twenty degree knee flexion view as compared to the forty-five degree view. This, however, has not been shown by the present study and no explanation is available for the difference in findings.

Lateral Patello-Femoral Angle

The lateral patello-femoral angle showed a statistically significant difference between the frequency of normal versus abnormal measurements in the chondromalacia patella group under study in both the twenty and forty-five degrees knee flexion views. These findings are not in complete agreement with Laurin, Levesque, Dussault, Labelle and Peides (1978) who found that the roentgenographic study was of no diagnostic value in one hundred patients with chondromalacia patella, since the angle was abnormal in ten patients and normal in ninety patients. These same authors did, however, find the lateral patello-femoral angle to be abnormal in every case of subluxating patella. As stated earlier, since no medical history was available on any of the patients in the present study, patella subluxation may have been a complication of the chondromalacia patella and may explain the greater frequency of abnormal findings in the present study.

No significant difference was found between the frequency of abnormal lateral patello-femoral angle in the twenty degree knee flexion view versus the forty-five degree view. This again is not in complete agreement with Laurin, Dussault and Levesque (1979) who found an abnormal lateral patello-femoral angle with greater frequency in the twenty degree view in subluxating patella, with a false normal x-ray present when the knee was flexed beyond twenty degrees. The fact that in the present study the patients were diagnosed as having chondromalacia of the patella and not primarily subluxating patella may be the reason for the discrepancy. Chondromalacia patients may have a patello-femoral alignment distinct from that found in subluxating patella.

Lateral Patellar Displacement

In both the twenty degree and the forty-five degree view, there was a statistically significant difference between the frequency of normal versus abnormal measurements on the lateral patellar displacement. The present findings are similar to those reported by Laurin, Dussault and Levesque (1979) who found thirty percent of their chondromalacia group displaying an abnormal lateral patellar displacement. In their patella subluxating group, all patients with an abnormal patellar displacement also demonstrated an abnormal lateral patello-femoral angle. However, no such relationship could be established in their chondromalacia group. When examining the data of the present study, five out of fifteen patients displayed both an abnormal lateral patellar displacement and an abnormal patello-femoral angle in the twenty degree view. The remaining ten patients with abnormal lateral patellar displacement had normal lateral patello-femoral angle which seem to point to chondromalacia patella as distinct from subluxating patella in these cases. In the forty-five degree view,

five patients displayed both an abnormal lateral patellar displacement and an abnormal lateral patello-femoral angle. Another five patients had an abnormal lateral patellar displacement with a normal lateral patello-femoral angle. There appeared to be some relationship between the patients displaying both abnormalities in the twenty degree view and those showing both abnormal measurements in the forty-five degree view, with three out of the five showing the abnormalities on both views.

When comparisons were made between the frequency of normal versus abnormal measurements in the twenty degree view versus the forty-five degree view, no statistically significant difference could be found. This does not agree with Laurin, Dussault and Levesque (1979) who pointed to the lateral patellar displacement as an x-ray sign of poor patellar tracking at twenty degrees flexion of the knee, which could not be seen on tangential films with the knee flexed beyond twenty degrees.

Many sources of error could have come into play with any of the measurements taken in the twenty degree and forty-five degree views resulting in a greater or lesser frequency of normal versus abnormal findings. Such errors may stem from changes in radiology staff resulting in small changes in individual technique. The x-ray beam and plate may not always have been placed at ninety degrees to one another, which, as pointed out by Brattström (1964) may have resulted in important changes in the outline of the patella and femoral condyles. The knees may not have been flexed to twenty degrees and forty-five degrees for each patient and may have altered the position of the patella in the sulcus. The patient may have contracted the quadriceps muscle, during the taking of the x-ray, therefore preventing any subluxation that may have occurred had one been relaxed. Any patient motion during the taking of the radiograph may have

been perceived on x-ray as true bone contour, when it could in actuality have been an overlying shadow. Difficulty in outlining the patella contour or the femoral condyles with precision may have resulted in errors of measurement. The possibility of human errors in measurement either in the use of the goniometer or the ruler, resulting in a greater or lesser number of abnormal measurements cannot be ruled out. Finally, differences in the population under study compared to the populations reported in the literature, to which the present findings were compared, may have been present and beyond the control of the author. All the potential sources of errors, just outlined, may have resulted in a greater or lesser difference in the measurement outcome which may, to a certain extent, explain the discrepancy observed in the present study as compared to the values reported in the literature.

Patella Length/Patella Tendon Length Ratio (P/PT)

Results of the P/PT ratio showed a statistical significance in the number of normal versus abnormal measurements in the chondromalacia of the patella group under study. All abnormal ratio measurements were smaller than the expected normal ratio, indicating a higher preponderance of patella alta in the chondromalacia patella group. No cases of patella infra or low riding patella were found in this study using the P/PT ratio. These findings are in agreement with Lancourt and Cristini (1975) who found a P/PT ratio of .86 in their chondromalacia group compared to a ratio of 1.0 in the normal population. Insall and Salvati (1971) also found a ratio of 1.02 in the normal population with deviations of twenty percent or more as being abnormal, but did not comment on a specific ratio for chondromalacia patella. With an abnormally high riding patella, as explained

by Knight (1978), the patello-femoral force must be borne by the patella articular surface alone for a much greater length of time, with increasing knee flexion, before it can be shared by the quadriceps tendon. The increase stress on the patellar articular surface due to the increase force it has to bear, as well as due to the incongruent opposing surfaces, all can lead to degenerative changes. The presence of patella alta associated with chondromalacia patella is also in accordance with Insall, Falvo and Wise (1976) who reported that patella alta or increases in Q-angle were present in most cases of chondromalacia patella.

Tibial Plateau Distance/Patella Articulation Surface Length Ratio (A/B)

The frequency of abnormal A/B ratio versus normal values has been shown to be statistically significant in the group under investigation. These findings are not in agreement with Blackburne and Peel (1977) who found no significant difference from the normal in their group of female chondromalacia patients. These same authors did, however, find a statistically significant difference in the A/B ratio in their group of male chondromalacia patients. All abnormal ratios found in the present study were greater than normal values, which point to the high occurrence of patella alta associated with chondromalacia patella.

This method of measuring patella height has been said (Blackburne and Peel, 1977) to be superior to the method devised by Insall and Salvati (1971), in cases where the tibial tubercle is not well demarcated or when there has been a traction apophysitis of the tibial tubercle distally or of the lower pole of the patella proximally. When comparing the results of the two methods, used to determine the patella height in the present study, thirteen cases of patella alta were found using the Insall and

Salvati method and eight cases of patella alta were found using the Blackburne and Peel method. Only four cases of patella alta were found to be present on both methods of assessment. Difficulties have arisen using either methods, which could have resulted in inaccuracies. Difficulties with the Insall and Salvati method were mainly due to the tibial tubercle not always being prominent, making it difficult to measure with great precision the patella tendon length. Errors in estimating the Blackburne and Peel ratio stemmed mainly from difficulties in assessing the exact limit of the tibial plateau especially when overlying shadows were present.

The fact that the lateral roentgenograms were taken with the knee flexed to ninety degrees rather than the thirty degrees reported in the literature (Blackburne and Peel, 1977; Insall and Salvati, 1971) does not appear to have had an effect on the outcome, since, as pointed out by Blackburne and Peel (1977), the measurements can be made on any lateral radiograph of the knee providing that the patella tendon is under tension, which as stated by these authors, occurs with the knee flexed beyond thirty degrees.

Patella Configuration

Statistically significant differences in the frequency of normal versus abnormal patella type were found in the group of chondromalacia patients under study. Wiberg's Type III patella (Wiberg, 1941) and Baumgartl's dysplastic patella (Baumgartl, 1964) were considered abnormal in the present study. The findings in this study are not in complete agreement with those of Wiberg (1941) who did not find a predominance of Type III patella in his chondromalacia group. A point of clarification must

be made here, in that the change from Type II patella to Type III patella is not an abrupt one. It occurs gradually and at times there is great difficulty in deciding whether a patella fits the Type II or Type III criteria. Without tomographic cuts, it remains very difficult to classify a patella as one or another type with clear certainty. The present findings do seem to agree with those of Baumgartl (1964), who stated that thirty-four percent of all people fall within the abnormal classification of patella with an eighty percent probability of developing patello-femoral problems.

The presence of significant findings in this current study suggest that certain abnormal radiographic measurements on the twenty and forty-five degree tangential view as well as on the ninety degree lateral view are closely associated with the clinical diagnosis of chondromalacia of the patella in the group under investigation. All the radiographic measurements conducted in the present study are related to the alignment of the patella in the intercondylar sulcus. Since abnormal radiographic measurements may result in abnormal stresses placed on different areas of articular cartilage, degeneration may occur in one area or another. The numerous abnormal measurements that may cause malalignment may help to explain the discrepancy in the literature as to the area of cartilage degeneration, the cause of chondromalacia patella, as well as the treatment of choice for the disorder. Radiographic views in either the twenty or forty-five degree tangential view and in the ninety degree lateral view should be carried out in all patients suspected of having chondromalacia of the patella and measurements such as sulcus angle, congruence angle, lateral patello-femoral angle, lateral patellar displacement, patella height and patella configuration, done to allow a better understanding

of the contributing causes of the disorder. These values would also permit a more objective means of treatment choice.

Chapter 6

SUMMARY AND CONCLUSIONS

Summary

The purpose of the present study was to assess the relationship of selected radiographic measurements, namely sulcus angle, congruence angle, lateral patello-femoral angle, lateral patellar displacement, patella height and patella configuration, to chondromalacia of the patella. Frequencies of normal versus abnormal measurements in the chondromalacia group were compared to the frequencies reported, by previous authors on normal populations, using Chi-square tests for nominal data. The sulcus angle, congruence angle, lateral patello-femoral angle and lateral patellar displacement were evaluated on tangential views of radiographs in both twenty and forty-five degrees knee flexion. Comparisons between the two views were made using a t-test for correlated samples for the sulcus angle and congruence angle, and a Z-test in difference in proportions for correlated samples for the lateral patello-femoral angle and lateral patellar displacement. The patella height was assessed on a ninety degree lateral radiographic view of the knee joint, and the patella configuration on a forty-five degree tangential radiographic view. A sample of sixty female subjects between the ages of fifteen and thirty-five years, having been diagnosed as having chondromalacia of the patella, were studied.

In accordance with the limitations and delimitations imposed on

the study, all measurements in the chondromalacia group proved to have a significantly greater frequency of abnormal measurements, compared to the normal populations reported in the literature, at the .01 or .001 level of confidence which supported the research hypothesis set forth. Measurements in the twenty degree radiographic view did not prove to be significantly different from those in the forty-five degree view except for the sulcus angle measurement. This is not in agreement with the second hypothesis set forth prior to conducting the study.

Conclusions

With the data available from the present study, the following conclusions were made:

(1) The frequency of abnormal measurements on the sulcus angle on tangential radiographic views in twenty and forty-five degrees knee flexion was greater in chondromalacia patella patients compared to the normal population, and there was a significant difference in the sulcus angle between the two views.

(2) The frequency of abnormal measurements on the congruence angle on tangential radiographic views in twenty and forty-five degrees knee flexion was greater in chondromalacia patella patients compared to the normal population, and there was no significant difference in the congruence angle between the two views.

(3) The frequency of abnormal measurements on the lateral patello-femoral angle on tangential radiographic views in twenty and forty-five degrees knee flexion was greater in chondromalacia patella patients compared to the normal population, and there was no significant difference in the lateral patello-femoral angle between the two views.

(4) The frequency of abnormal measurements on the lateral patellar displacement on tangential radiographic views in twenty and forty-five degrees knee flexion was greater in chondromalacia patella patients compared to the normal population, and there was no significant difference in the lateral patellar displacement between the two views.

(5) The frequency of abnormally small patella length/patella tendon length ratio (P/PT) assessed on ninety degree lateral radiographic view of the knee was greater in chondromalacia patella patients compared to the normal population, meaning that chondromalacia patella patients had an abnormally high riding patella or patella alta.

(6) The frequency of abnormally large tibial plateau distance/patella articulation surface length ratio (A/B) assessed on ninety degree lateral radiographic view of the knee was greater in chondromalacia patella patients compared to the normal population, meaning that chondromalacia patella patients had an abnormally high riding patella or patella alta.

(7) Chondromalacia patella patients had a greater number of abnormally shaped patella conforming to Wiberg's Type III patella or Baumgartl's dysplastic patella as compared to the normal population.

The results of the study strongly suggest that anatomical and functional malalignments are present in many cases of chondromalacia of the patella which can readily be assessed on a twenty degree or forty-five degree tangential radiographic view of the patello-femoral joint and on a ninety degree lateral radiographic view of the knee joint. Measurements can then be made on these radiographs which will allow a more definitive means of diagnosing the disorder and a more objective means of determining the type of treatment to institute for each patient.

Recommendations

The major recommendations that can be made from the current study are as follows:

(1) A guide be established for the taking of tangential view x-rays to ensure accuracy and precision in every knee filmed in this manner.

(2) Definite anatomical landmarks, and means of finding these points, be established to allow the measurements outlined in this study to become universal measurements.

(3) Establishment of a more objective means of determining the patella configuration and better criteria for the classification of different types of patella.

(4) Since data is lacking on precisely defined normal populations, it is recommenced that research be directed towards improving this area.

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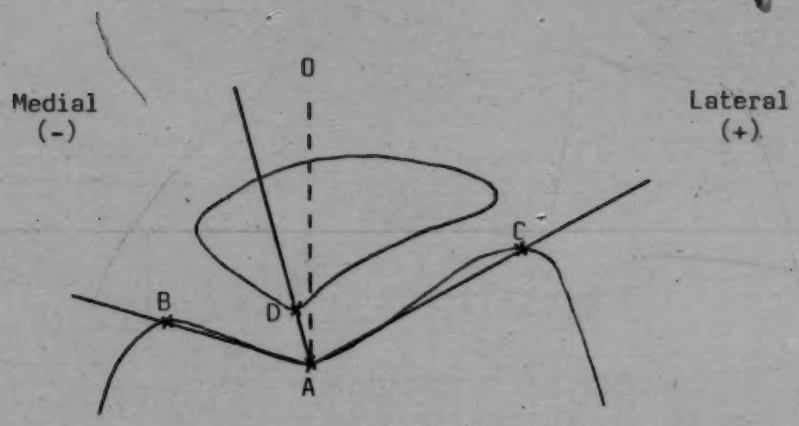
APPENDICES

APPENDIX A

Determination of Congruence Angle

Determination of Congruence Angle



Axial view of the patello-femoral joint in twenty degrees of knee flexion.

1. The sulcus angle BAC (see Appendix H) is bisected to establish a zero reference line AO.
2. The lowest point on the articular ridge of the patella (D) is joined to the lowest point on the intercondylar sulcus (A) and the line AD is projected.
3. The angle DAO is termed the congruence angle.

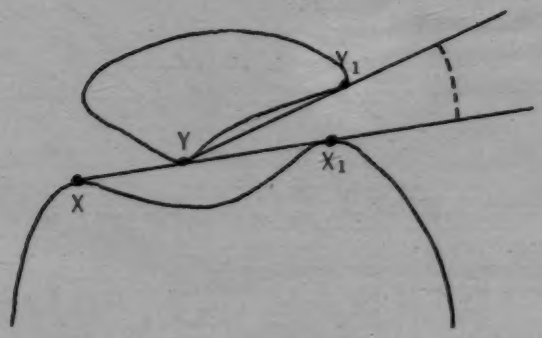
All values medial to the zero reference line AO are designated as minus and those lateral as plus. Normal: $\bar{x} = -6^{o}$, SD = 11^{o} (Merchant, Mercer, Jacobsen and Cool, 1974).

The point D is found by tracing the outline of the lateral facet of the patella towards the median. The area at which an abrupt change in angle occurs is designated as point D.

APPENDIX B

Determination of Lateral Patello-Femoral Angle

Determination of Lateral Patello-Femoral Angle



Axial view of the patello-femoral joint in twenty degrees flexion.

X = highest point on medial condyle of femur

X_1 = highest point on lateral condyle of femur

Y = lowest point on the articular ridge of the patella

Y_1 = upper limit of the lateral patellar facet

Join the points X and X_1 and the points Y and Y_1.

The angle (Y_1,Y,X_1) formed by the intersection of these two lines determines the lateral patello-femoral angle (Laurin, Levesque, Dussault, Labelle, and Peides, 1978).

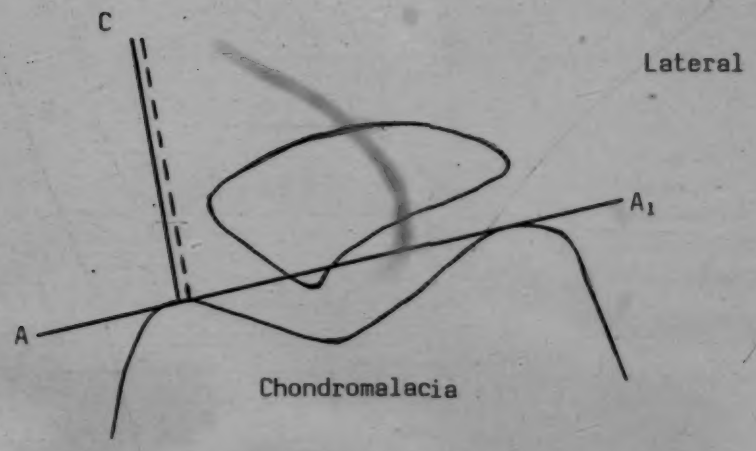
Normal : the angle Y_1,Y,X_1 opens laterally

Abnormal : the angle Y_1,Y,X_1 opens medially or the line Y Y_1 is parallel to the line X X_1.

APPENDIX C

Determination of Lateral Patellar Displacement

Determination of Lateral Patellar Displacement



A skyline view of the patello-femoral joint in twenty degrees flexion.

1. Line A A_1 joins the summits of the femoral condyles.
2. Line C is drawn at ninety degrees to line A and arises from the medial femoral condyle.
3. Normal candidates: The medial edge of the patella is medial to line C in ninety-seven percent of patients. If the line C is displaced towards the intercondylar groove by one millimeter to its original landmark, it can be stated that the medial edge of the normal patella is medial to line C in all normal individuals.

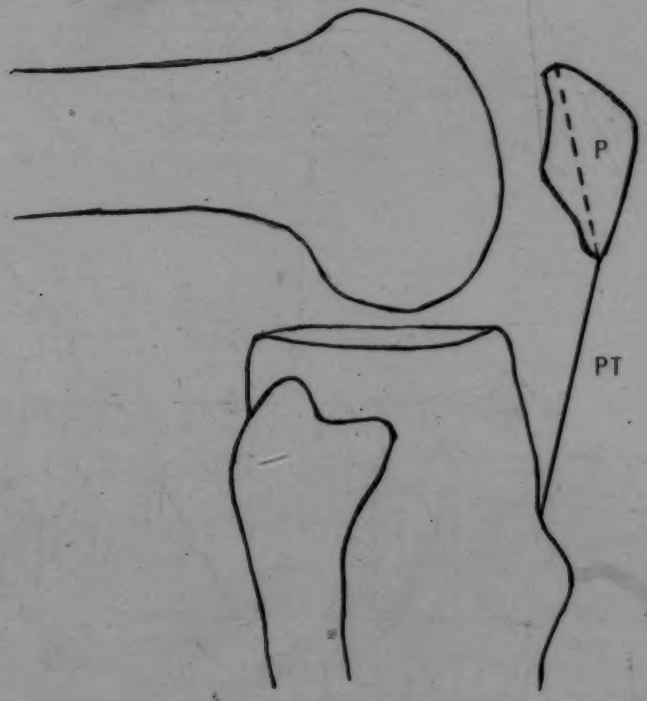
In subluxating patellae, only forty-seven percent had such a relationship with line C; in the remaining fifty-three percent of patients, the medial edge of the patella either touched that line or was lateral to it.

In chondromalacia patella, the patella was noted to be laterally displaced in thirty percent of individuals (Laurin, Dussault, and Levesque, 1979).

APPENDIX D

Determination of P/PT Ratio

Determination of P/PT Retio



Lateral view of the knee joint in ninety degrees flexion.

P: greatest diagonal length of the patella

PT: length of patella tendon, from inferior pole of the patella to upper surface of tibial tubercle.

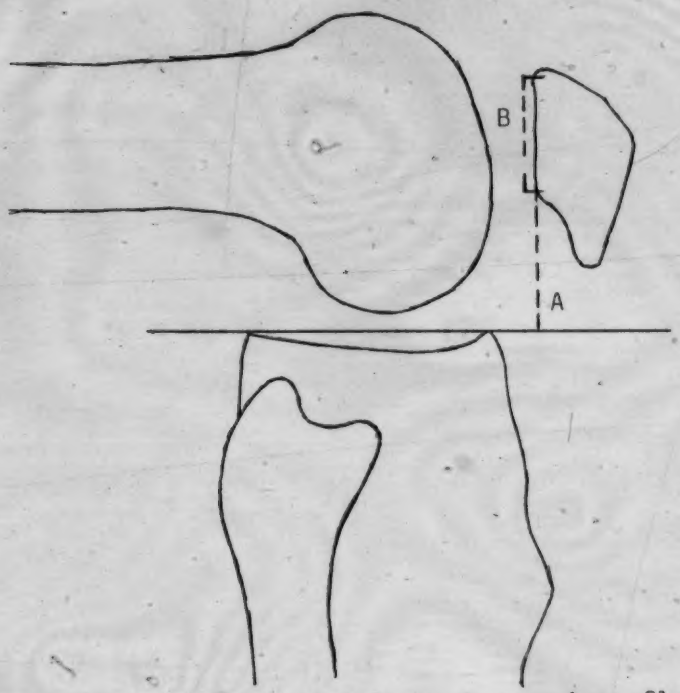
Normal P/PT: $\bar{x}$ = 1.02 (Insall and Salvati, 1971).
SD = 0.13

In cases where two projections appeared to represent the tibial tubercle, the uppermost projection was chosen as the point of attachment for the patella tendon.

APPENDIX E

Determination of A/B Ratio

Determination of A/B Ratio



Lateral view of the knee in ninety degrees knee flexion.

B: articular length of the patella on its posterior surface

A: distance from the lower pole of the patella articulating surface to the tibial plateau.

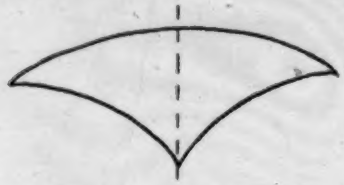
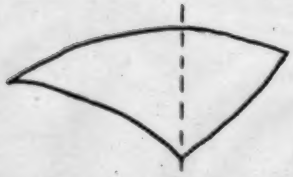
The tibial plateau is found by following the tibial spine anteriorly to the anterior surface of the tibia.

Normal A/B: $\bar{x}$ = 0.8, SD = 0.14 (Blackburne and Peel, 1977).

APPENDIX F

Determination of Patella Configuration

Determination of Patella Configuration

Type	Lateral Facet / Medial Facet	Characteristics
Wiberg Type I		Both facets are concave and roughly the same size.
Wiberg Type II		Medial facet slightly smaller and is flat or slightly concave.
Wiberg Type III		Medial facet considerably smaller and convex.
Baumgartl		Medial facet is very small or absent. Patella is almost flat.

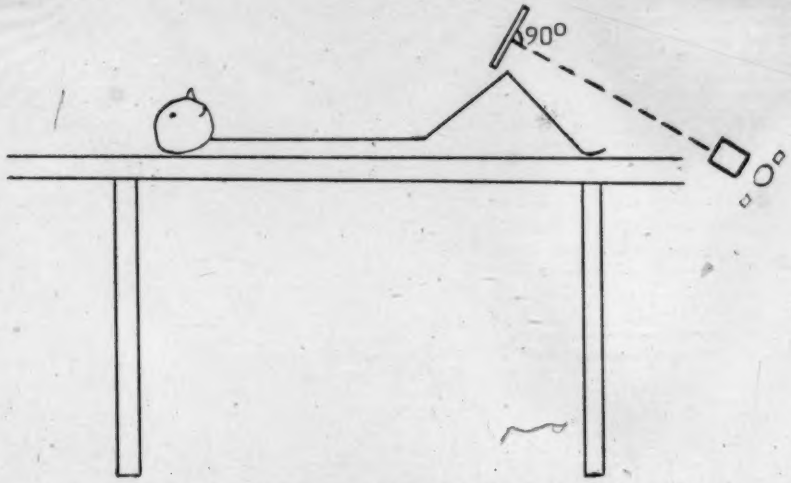
(Wiberg, 1941; Baumgartl, 1964)

Wiberg's Type III and Baumgartl's dysplastic patella are both considered abnormal.

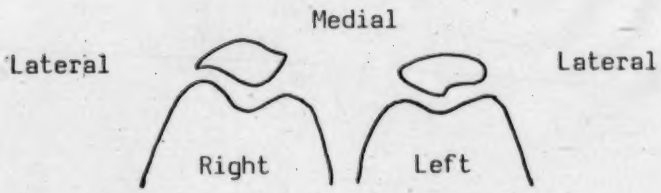
APPENDIX G

Skyline View

Skyline View



X-ray Technique: The knee is positioned at twenty degrees or forty-five degrees of flexion (zero degrees being full extension). The x-ray source is below the table top and directed in the cephalad direction; the x-rays are parallel to the anterior border of the tibia and the patello-femoral interspace; the x-ray plate is at ninety degrees to the x-rays and to the patello-femoral interspace (Laurin, Dussault and Levesque, 1979).

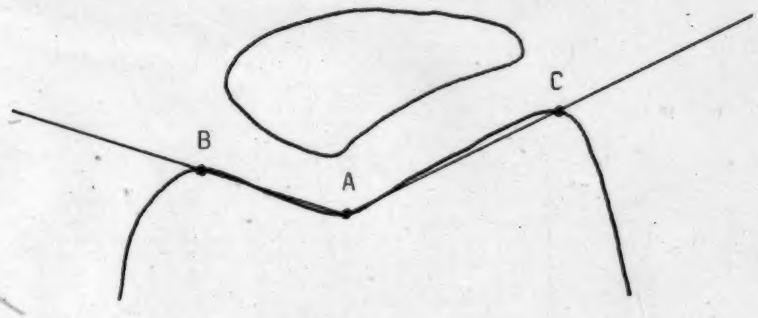


Diagrammatic representation of the skyline view seen on x-ray.

APPENDIX H

Determination of Sulcus Angle

Determination of Sulcus Angle



Axial view of the patello-femoral joint with the knee flexed to twenty degrees knee flexion.

A - lowest point on intercondylar sulcus

B - highest point on medial condyle of femur

C - highest point on lateral condyle of femur

Angle BAC is the sulcus angle.

Normal: $\bar{x} = 142^{o}$, SD = 6^{o} (Brattstrom, 1964).

The point A is found by tracing the lateral femoral condyle towards the intercondylar sulcus until a point where an abrupt change in angle occurs. This area is designated as point A.

APPENDIX I

Data Acquisition Form

DATA ACQUISITION FORM

Date of Reading: _____ Patient Number: _____

Knee Involved (✓) Date of Birth: _____

Right ___ Left ___ Both ___ Age at Time of X-ray: _____

Group: _____

90° FLEX FILM

	Left	Right
Patella Length		
Patella Tendon		
Ratio P/PT		
Patella Alta		
Normal		
Patella Infra		
Articular Surface A		
Plateau Distance B		
Ratio A/B		

20° TANGENTIAL VIEW

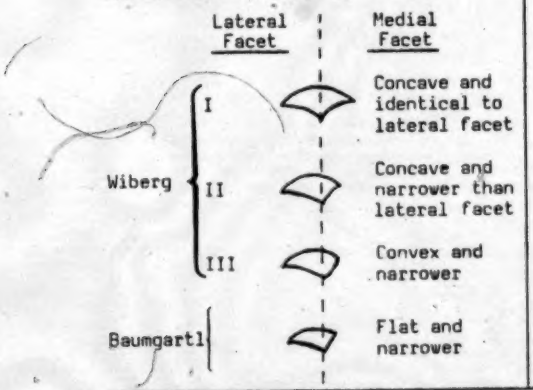
	Left	Right
Sulcus Angle		
Angle of Congruence		
Lateral Patello-Femoral Angle (D.N.C.)		
Lateral Patellar Displacement		

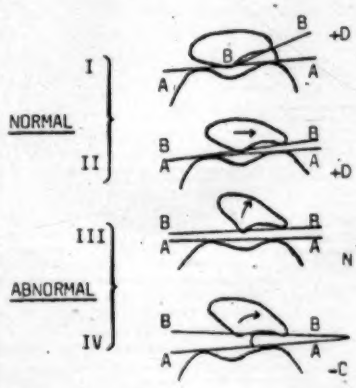
45° TANGENTIAL VIEW

	Left	Right
Sulcus Angle		
Angle of Congruence		
Lateral Patello-Femoral Angle (D.N.C.)		
Lateral Patellar Displacement		

Types of Patellar Contour

Classification Based on Different Contours of the Medial Facet (Lateral Facet Always the Same)





Comments: _____

APPENDIX J

Author's Reply Letters on Normal Population Descriptions

BARNET GENERAL HOSPITAL

THE BARNET FINCHLEY HEALTH DISTRICT

TEL 01 440 5111

Your Ref.

Our Ref.

WELLHOUSE LANE,
BARNET, HERTS.
EN5 3DJ

JSB/NKM 2nd March, 1981

Ms. Roberta Nowlan-Smith,
Department of Physical Therapy,
Rehabilitation Medicine,
University of Alberta,
Edmonton,
Alberta,
T6G2G4
Canada.

Dear Ms. Nowlan-Smith,

Thank you for your letter in which you enquire about the precise description of the population I used in my article for measuring the height of the patella.

Measurements were made on consecutive unselected cases of patients who attended for lesions of the knee which were definitely diagnosed as meniscal lesions, without any other abnormality being present.

Yours sincerely,

J. S. Blackburne, F.R.C.S.
Consultant Orthopaedic Surgeon

JEROLD E. LANCOURT, M.D.

ORTHOPEDIC SURGEON
ST. JOSEPH ORTHOPEDIC ASSOCIATES, INC.
1335 VILLAGE DRIVE
ST. JOSEPH, MISSOURI 64506

Telephone
(816) 233-0211

Diplomat American
Board of Orthopedic
Surgery

March 4, 1981

Roberta Nowlan-Smith
Department of Physical Therapy
Rehabilitation Medicine
University of Alberta,
Edmonton, Alberta
T6G2G4, Canada

Dear Ms. Nowlan-Smith:

I received your letter of February, 1981. My normal population was 17 to 19-year-old males. I did this study when I was in the Army and this was a fairly homogeneous population of young recruits. I think this would probably be at some variance and over a tighter range than your randomly selected females. For one, the height is more homogeneous in the service where the very short and the very tall are excluded.

In my normal population, even if the patients were asymptomatic, if they had any grating at all on examination, I eliminated them from the normal group.

I was also very specific about my diagnosis of chondromalacia. They really had to satisfy six of the eight criteria that I listed in my article.

I hope this information is of value. Please let me know what your results are - I would be most interested.

Sincerely,

Jerold E. Lancourt, M.D.

JEL:sg

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Joseph I. Seder, D.P.M.
Garron G. Weiker, M.D.

March 17, 1981

Roberta Nowlan-Smith
Department of Physical Therapy
Rehabilitation Medicine
University of Alberta
Edmonton, Alberta
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Dear Ms. Nowlan-Smith:

Thank you very much for your recent letter regarding my paper on Chondromalacia of the Patella. The average P:PT ratio for a female was 0.91. The female control group was 30 woman ages 14 to 30 years who had undergone an arthrotomy for a torn meniscus. That age group was chosen because it matched the age group of the experimental group. Previous to the injury which tore the control group's meniscus, none had knee problems. The age range and the median ages were similar in both the control and experimental group. I hope that this additional information will help you in your research project.

Sincerely,

K. E. Marks

Kenneth E. Marks, M.D.

KEM/jm

APPENDIX K

Correlation of Reliability

Correlation of Reliability

Pearson product moment correlation coefficient, comparing the author's measurements to those of an orthopaedic surgeon's, were performed using the following equation:

$$r = \frac{N \Sigma XY - \Sigma X \Sigma Y}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2]\,[N\Sigma Y^2 - (\Sigma Y)^2]}}$$ (Ferguson, 1976)

The following measurements were analyzed in this manner: sulcus angle; congruence angle; patella length; patella tendon length; patella articular length; and, tibial plateau distance.

X, represents the author's measurements and Y, represents the orthopaedic surgeon's measurements. The r equals the Pearson product-moment correlation coefficient value obtained and the p is the significance of the correlation value.

Sulcus Angle (Degrees)		Congruence Angle (Degrees)		Patella Length (mm)		Patella Tendon Length (mm)		Patella Articular Length (mm)		Tibial Plateau Distance (mm)	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
133	131	- 4	- 5	44	46	47	46	28	30	34	34
140	139	-12	- 9	43	43	43	42	24	24	34	34
151	149	+29	+27	42	41	47	47	28	30	33	33
145	145	- 5	- 7	41	41	50	50	30	29	34	34
142	142	- 3	- 3	47	47	57	57	38	37	38	37
144	145	+ 3	+ 4	40	40	57	56	32	31	31	30
133	132	-12	-11	43	44	49	47	31	31	34	34
135	133	-12	-14	47	47	49	48	28	27	32	31
140	142	- 9	- 8	43	43	40	40	29	30	27	27
130	132	-22	-20	45	44	55	56	26	26	37	36
129	129	+ 6	0								
r = .977 p<.001		r = .957 p<.001		r = .937 p<.001		r = .990 p<.001		r = .950 p<.001		r = .986 p<.001	

Measurements for the lateral patello-femoral angle, lateral patellar displacement and patella configuration were simply recorded as equal or

different, when assessed by the two observers. A percentage value, representing the equal values, was then calculated.

Lateral Patello-Femoral Angle		Lateral Patellar Displacement		Patella Configuration	
X	Y	X	Y	X	Y
+	+	-	-	I	I
-	-	-	-	III	III
-	-	-	-	III	III
+	+	-	-	III	III
+	+	-	-	III	III
+	+	-	-	II	II
+	+	-	-	II	II
+	+	-	-	III	III
+	+	-	-	II	II
+	+	-	-	II	III
+	+	-	-		
100 percent agreement was found		100 percent agreement was found		90 percent agreement was found	

APPENDIX L

Raw Data

1	01	144	144	000	P05	P	P	N	P
2	02	133	138	N04	N03	P	P	N	N
3	03	147	145	P15	P12	N	P	P	P
4	04	144	140	N10	P12	P	P	N	N
5	05	135	137	N17	N04	P	P	N	N
6	06	138	142	N19	P10	P	P	N	P
7	07	144	140	N10	N22	P	P	N	N
8	08	137	135	N18	N18	P	P	N	N
9	09	155	135	P08	P10	N	N	P	P
10	10	146	145	N06	N05	P	P	P	N
11	11	165	165	N03	N90	P	P	P	N
12	12	140	157	P04	P05	P	P	N	P
13	13	148	148	N08	P02	P	P	N	N
14	14	154	154	P16	P16	P	P	P	P
15	15	133	136	N12	P02	P	P	N	N
16	16	137	135	N07	N04	P	P	N	N
17	17	132	130	P09	P18	P	P	N	N
18	18	XXX	XXX	XXX	XXX	X	X	X	X
19	19	134	133	N08	N10	P	P	N	P
20	20	133	128	N19	N13	P	P	N	N
21	21	139	138	P03	P09	P	P	N	N
22	22	143	142	N20	N10	P	P	N	N
23	23	XXX	XXX	XXX	XXX	X	X	X	X
24	24	XXX	XXX	XXX	XXX	X	X	X	X
25	25	144	145	P02	P19	P	P	N	N
26	26	130	130	N40	N32	P	P	N	N
27	27	133	142	N13	N05	P	P	N	N
28	28	135	132	000	N05	P	P	N	N
29	29	153	155	N13	N18	P	P	N	N
30	30	140	137	N09	N10	P	P	N	N
31	31	145	147	N04	P07	N	P	P	N
32	32	145	142	N20	N12	P	P	N	N
33	33	135	134	N12	N10	P	P	N	N
34	34	129	130	P07	N03	P	P	P	P
35	35	130	125	N22	N20	P	P	N	N
36	36	147	140	N18	N09	P	P	N	N
37	37	138	140	N05	N15	P	P	N	N
38	38	140	140	N11	N05	P	P	N	N
39	39	140	136	N17	N10	P	P	N	P
40	40	138	144	N25	N25	P	P	N	N
41	41	136	140	N09	N05	P	P	N	P
42	42	141	140	N10	N03	P	P	N	N
43	43	155	162	N05	N05	N	N	N	P
44	44	131	136	N13	N02	P	P	N	N
45	45	148	150	N18	N03	P	P	N	N
46	46	148	140	P21	P26	N	N	P	P
47	47	136	137	N10	000	P	P	N	N
48	48	126	122	N08	N12	P	P	N	N
49	49	XXX	XXX	XXX	XXX	X	X	X	X
50	50	130	133	N17	N03	P	P	N	N
51	51	123	137	N19	N20	P	P	N	N
52	52	XXX	XXX	XXX	XXX	X	X	X	X
53	53	XXX	XXX	XXX	XXX	X	X	X	X
54	54	XXX	XXX	XXX	XXX	X	X	X	X
55	55	XXX	XXX	XXX	XXX	X	X	X	X
56	56	XXX	XXX	XXX	XXX	X	X	X	X
57	57	XXX	XXX	XXX	XXX	X	X	X	X
58	58	XXX	XXX	XXX	XXX	X	X	X	X
59	59	XXX	XXX	XXX	XXX	X	X	X	X
60	60	XXX	XXX	XXX	XXX	X	X	X	X

Raw data for: sulcus angle, congruence, lateral patello-femoral angle and lateral patellar displacement in twenty degree tangential view. P = positive, N = negative, and x = data unavailable. Read 144 and 144 sulcus angle left and right knee; 000 and P05 congruence angle left and right knee; P and P lateral patello-femoral angle left and right knee; and, N and P lateral patellar displacement left and right knee.

1	01	140	144	N10	P03	P	P	N	P	2	2
2	02	130	133	N11	N05	P	P	N	N	1	1
3	03	138	140	N05	N12	P	P	P	P	3	3
4	04	140	138	N07	N10	P	P	N	N	3	3
5	05	133	130	N03	N05	P	P	N	N	2	2
6	06	133	133	N17	N09	P	P	N	N	3	3
7	07	132	130	N17	N14	P	P	N	N	2	2
8	08	140	135	N12	N10	N	N	N	N	3	3
9	09	151	148	P29	P21	N	N	N	P	3	3
10	10	142	142	N03	N03	P	P	N	N	3	3
11	11	168	166	P44	N55	N	P	P	N	3	4
12	12	144	150	P03	N05	P	P	N	N	3	3
13	13	148	148	N16	N18	P	P	N	N	2	2
14	14	136	142	P08	P08	P	P	N	N	3	3
15	15	138	132	N13	N02	P	P	N	N	2	2
16	16	130	130	N19	N15	P	P	N	N	2	2
17	17	125	127	P03	P10	P	P	N	N	3	3
18	18	125	130	N29	P10	P	P	N	N	3	3
19	19	134	135	N19	N11	P	P	N	N	3	3
20	20	131	126	N17	N17	P	P	N	N	2	2
21	21	136	136	000	P08	P	P	N	N	3	3
22	22	146	145	N19	N09	P	P	N	N	3	3
23	23	143	140	N18	N18	P	P	N	P	3	3
24	24	138	146	N28	N18	P	P	N	N	3	3
25	25	138	138	N20	N10	P	P	N	N	3	3
26	26	128	130	N15	N05	P	P	N	N	2	2
27	27	132	138	N15	N18	P	P	N	N	2	2
28	28	140	130	N06	N04	P	P	N	N	3	3
29	29	154	149	N15	N20	P	P	N	N	3	3
30	30	140	141	N14	N06	P	P	N	N	3	3
31	31	148	149	N19	N10	N	P	N	N	2	2
32	32	138	137	N10	N22	N	P	P	N	2	2
33	33	133	132	000	N02	P	P	N	N	2	2
34	34	130	138	N07	N15	P	P	N	N	3	3
35	35	134	130	N20	N16	P	P	N	N	2	2
36	36	140	151	N07	N20	P	P	N	N	3	3
37	37	139	135	N10	N10	P	P	P	P	2	2
38	38	140	135	N28	N43	P	P	N	N	1	1
39	39	136	133	N04	P09	P	P	N	P	3	3
40	40	128	133	N15	N09	P	P	P	P	2	2
41	41	140	140	N12	P05	P	P	N	N	3	3
42	42	137	139	N15	N16	P	P	N	N	2	2
43	43	150	151	P20	P19	N	N	P	P	3	3
44	44	135	130	N11	N12	P	P	N	N	3	3
45	45	144	142	N22	N13	P	P	N	N	2	2
46	46	145	140	P05	P13	P	N	P	P	4	4
47	47	135	135	N13	N19	P	P	N	N	3	3
48	48	128	126	N11	N10	P	P	N	N	2	2
49	49	130	135	N16	N07	P	P	N	N	3	3
50	50	125	130	N05	P05	P	P	N	N	3	3
51	51	135	131	N05	N05	P	P	N	N	3	3
52	52	130	125	N07	N05	P	P	N	N	3	3
53	53	148	146	P26	P36	N	N	P	P	3	3
54	54	140	142	P03	P03	P	P	N	P	3	3
55	55	145	XXX	N03	XXX	P	X	P	X	3	X
56	56	140	140	P08	000	P	P	N	N	1	1
57	57	136	135	N10	N09	N	N	P	P	3	3
58	58	136	137	N31	N18	P	P	N	P	2	2
59	59	145	142	P25	N15	P	P	P	P	4	4
60	60	162	170	P64	P78	N	N	P	P	4	4

Raw data for: sulcus angle, congruence angle, lateral patello-femoral angle, lateral patellar displacement and patella configuration in forty-five degree tangential view. P = positive, N = negative, and x = data unavailable. Read 140 and 144 sulcus angle left and right knee; N10 and P03 congruence angle left and right knee; P and P lateral patello-femoral angle left and right knee; N and P lateral patellar displacement left and right knee; and, 2 and 2 patella configuration left and right knee.

1	01	47	45	49	50	.96	.90	29	27	34	34	.85	.79
2	02	45	44	48	47	.94	.94	26	28	34	34	.77	.82
3	03	42	44	60	54	.70	.81	36	34	34	36	1.1	.94
4	04	43	40	46	46	.94	.87	24	26	32	32	.75	.81
5	05	43	43	40	38	1.1	1.1	22	24	29	27	.76	.89
6	06	37	35	44	45	.84	.78	26	28	29	28	.90	1.0
7	07	44	41	44	47	1.0	.87	22	26	31	31	.71	.84
8	08	43	40	43	45	1.0	.89	24	23	34	33	.71	.70
9	09	44	42	43	47	1.0	.89	27	28	31	33	.87	.85
10	10	41	47	50	45	.82	1.0	30	27	34	34	.88	.79
11	11	46	XX	69	XX	.67	XXX	29	58	35	30	.83	2.0
12	12	47	47	61	57	.77	.76	38	38	38	38	1.0	1.0
13	13	42	42	42	48	1.0	.88	29	29	32	31	.91	.94
14	14	40	40	54	48	.74	.83	31	24	31	28	1.0	.86
15	15	41	40	41	57	1.0	.70	29	32	31	31	.94	1.0
16	16	45	44	50	50	.90	.88	27	29	34	34	.79	.85
17	17	46	45	58	58	.79	.78	30	29	37	35	.81	.83
18	18	XX	XX	XX	XX	XXX	XXX	XX	XX	XX	XX	XXX	XXX
19	19	46	46	44	41	1.1	1.1	26	24	37	37	.70	.65
20	20	44	44	54	51	.82	.86	29	27	34	35	.85	.77
21	21	49	49	52	52	.94	.94	29	27	37	37	.78	.73
22	22	44	44	46	44	.96	1.0	34	33	28	29	1.2	1.1
23	23	42	42	41	42	1.0	1.0	25	24	33	34	.76	.71
24	24	43	44	70	58	.61	.76	41	44	36	32	1.1	1.4
25	25	47	45	56	60	.84	.75	34	36	34	37	1.0	.97
26	26	47	45	51	52	.92	.87	31	30	34	34	.91	.88
27	27	46	46	52	50	.89	.92	28	28	37	37	.76	.76
28	28	45	45	48	50	.94	.90	32	30	35	35	.91	.86
29	29	44	44	50	54	.88	.82	29	31	35	35	.83	.89
30	30	43	45	53	49	.81	.92	26	28	34	35	.77	.80
31	31	45	45	56	53	.80	.85	34	35	35	34	.97	1.0
32	32	46	45	50	46	.92	.98	31	30	33	33	.94	.91
33	33	43	45	49	46	.88	.98	31	30	34	35	.91	.86
34	34	44	45	51	55	.86	.82	27	26	36	37	.75	.70
35	35	43	44	40	40	1.1	1.1	27	29	29	30	.93	.97
36	36	47	48	49	46	.96	1.0	28	30	32	33	.88	.91
37	37	46	45	44	44	1.1	1.0	29	30	36	36	.81	.83
38	38	41	41	45	45	.91	.91	31	32	25	25	1.2	1.3
39	39	41	40	47	50	.87	.80	32	33	32	31	1.0	1.1
40	40	46	46	43	44	1.1	1.1	24	29	34	36	.71	.81
41	41	39	38	54	53	.72	.72	33	34	32	32	1.0	1.1
42	42	43	45	51	49	.84	.92	29	36	34	34	.85	1.1
43	43	45	45	60	57	.75	.79	33	34	39	37	.85	.92
44	44	41	41	48	48	.85	.85	28	32	33	33	.85	.97
45	45	42	41	45	47	.93	.87	27	28	35	33	.78	.85
46	46	52	50	62	63	.84	.79	43	46	43	41	.98	1.1
47	47	40	41	46	41	.87	1.0	24	23	29	31	.83	.74
48	48	XX	XX	XX	XX	XXX	XXX	XX	XX	XX	XX	XXX	XXX
49	49	51	50	51	50	1.0	1.0	29	30	38	37	.76	.81
50	50	37	38	50	50	.74	.76	28	27	32	33	.88	.82
51	51	54	XX	56	XX	.96	XXX	26	XX	40	XX	.65	XXX
52	52	47	47	54	55	.87	.85	30	27	38	38	.79	.71
53	53	XX	XX	XX	XX	XXX	XXX	XX	XX	XX	XX	XXX	XXX
54	54	44	46	59	57	.75	.81	36	35	35	35	1.0	1.0
55	55	42	XX	50	XX	.84	XXX	31	XX	32	XX	.97	XXX
56	56	43	42	63	61	.68	.69	36	36	34	35	1.1	1.0
57	57	47	48	50	48	.94	1.0	30	31	34	34	.88	.91
58	58	45	46	62	58	.73	.79	32	32	38	39	.84	.82
59	59	XX	XX	XX	XX	XXX	XXX	XX	XX	XX	XX	XXX	XXX
60	60	XX	XX	XX	XX	XXX	XXX	XX	XX	XX	XX	XXX	XXX

Raw data for: patella length, patella tendon length, P/PT ratio, patella articular surface, tibial plateau distance, A/B ratio in ninety degree lateral view. x = data unavailable. Read 47 and 45 patella length left and right knee; 49 and 50 patella tendon length left and right knee; .96 and .90 P/PT ratio left and right knee; 29 and 27 patella articular surface left and right knee; 34 and 34 tibial plateau distance left and right knee; .85 and .79 A/B ratio left and right knee.